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MAP AND AERIAL PHOTOGRAPH READING

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MAP AND AERIAL PHOTOGRAPH READING

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SECTION 1

GENERAL

1. **Purpose.**—The purpose of this manual is to present in simplified form necessary information for instruction of all military personnel in elementary map and aerial photograph reading.

2. **Scope.**—a. This manual covers elementary map reading, including conventional signs and military symbols, distances and scales, directions and azimuths, coordinates, relief, slopes, profiles and visibility, map reading in the field, and aerial photograph reading, to an extent sufficient to permit noncommissioned officers and platoon leaders to read maps, aerial photographs, and aerial mosaics.

3. **Necessity for Training.**—Modern warfare makes it essential that personnel of all grades have the ability to read maps and aerial photographs. The detailed study of maps assists higher commanders in arriving at their tactical decisions. In transmitting orders, they often will use maps which outline their plans to their subordinate commanders. In order to carry out these orders intelligently, the subordinate commanders must be able to read any type of map involved. Maps are used to move various combat units to their assigned positions and to identify their boundaries, areas, and objectives. The supporting fires of many weapons are usually controlled by use of map data. Frequently soldiers will be given individual missions requiring them to travel long distances with only a map as a guide. Since aerial photographs or photomaps made from aerial photographs are constantly being used as maps or to supplement maps, the necessity for training in their use is equally important as training in use of maps.

4. **Maps and Aerial Photographs.**—A map is a graphic, conventionalized representation to scale of a portion of the surface of the earth as a plane surface. Not all maps or map substitutes, however, satisfy all the requirements of this generalized definition. Types of maps or aerial photographs generally issued to troops will vary a great deal depending on location of operations. Large scale topographic maps desirable for tactical operations of small units exist for only limited areas, so some of lesser accuracy normally may be expected. These may range from ordinary automobile road maps to some type of map substitute. Various types of maps and map substitutes which may be encountered are:

a. **Maps compiled from existing maps.**—Normally troops may expect to be furnished some type of map hastily compiled from such maps as exist at the outbreak of hostilities. These maps may vary from crude, small scale maps such as ordinary automobile road maps, to accurate, large scale,

topographic maps. Large scale topographic maps suitable for tactical operations of small units may be expected only in isolated areas of limited size.

b. **Map substitutes.**—This is a general term used to designate substitute maps that may be produced in a few hours. The map substitutes may consist of direct reproduction of wide coverage aerial photographs, photomaps or mosaics, or of provisional maps. The term "photomap" is used as a general term to describe reproductions of various types of aerial photographs. A provisional map is produced by compiling existing map detail or by tracing information from aerial photographs.

c. **Battle maps.**—This is a map prepared normally from aerial photographs on a scale of 1:20,000, which is suitable for tactical and technical needs of all arms. Normally, this type of map would not be made available for any extensive area until at least 3 weeks after outbreak of hostilities.

5. **Map Classification.**—Military maps are generally classified according to scale. The general types are:

a. **Small.**—Maps of small scale varying from 1:1,000,000 to 1:7,000,000 are needed for general planning and strategical studies by the commanders of large units.

b. **Intermediate.**—Maps of intermediate scale, normally from 1:200,000 to 1:500,000 are required for planning operations, including movements, concentration, and supply of troops.

c. **Medium.**—Maps of a medium scale, that is, from 1:50,000 to 1:125,000 are needed for strategical, tactical, and administrative studies by units ranging in size from a corps down to a regiment. The compiled map described in paragraph 4a is of this type.

d. **Large.**—Large scale maps, generally of a scale not greater than 1:20,000 are intended for this technical and tactical battle needs of field artillery and infantry. Paragraph 4c describes this type.

6. **Limitations of Maps.**—A spherical surface cannot be reproduced as a plane surface with absolute accuracy, just as the skin of half an orange cannot be flattened without splitting the rind; therefore, any representation is an approximation only with limitations depending on the projection used. Most military maps use a type of prejection known as **polyconic** because it limits the distortion involved. Due to changes in atmospheric conditions, the paper on which a map is printed may shrink or expand. During the printing process, one lithographic plate is used for each color, hence any amount of slipping with relation to the plate may make considerable difference in the relative position of a contour and any other symbol on the map. For these reasons two copies of the same

edition of a map may have considerable variance. Distances, coordinates, or elevations taken from one map will not agree to the last decimal or foot with those taken from another. Radical differences, however, indicate errors in location or in obtaining data.

Survey methods of mapping are slow, expensive, and cumbersome. Their degree of accuracy is never all that might be expected. Seldom do they meet military requirements, particularly when fire control problems are involved. Moreover, it is interesting to note that only 1% of the United States is mapped to a scale of 1:20,000, the minimum requisite for artillery usages; only 12% is mapped to a scale of 1:62,500, the standard for tactical usage; and 85% is either inadequately mapped or the maps are so old or were made by such crude methods that they do not satisfy modern needs. For these reasons, recourse is had to aerial photographs, which will be studied later.

7. Marginal Information.—All military maps and most other maps show additional information along their margins. This is sometimes called the "map legend" and while it varies in detail and degree a study of the margins will generally reveal at least the following:

a. The name or title of the sheet and the general area covered.

b. The scale of the map expressed in several ways.

c. The direction of true, magnetic, and grid (if any) north lines.

d. The organization that made or supervised the original survey or revision.

e. The date of the original survey and subsequent revisions.

f. The organization issuing the map.

g. Adjacent sheet in the same series if any.

h. Unusual conventional signs or symbols.

i. The contour interval.

j. The projection used.

All these things tend to indicate the uses and limitations as well as the accuracy and reliability of the map under consideration and should be carefully studied and evaluated before using the map.

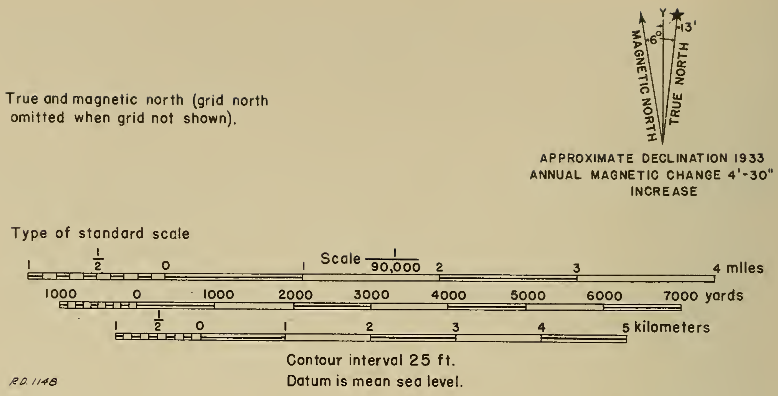

Figure 1.—Declination diagram and graphic scales.

Marginal information should appear on all standard military maps. The above are examples of such marginal information.

8. **Overlays.**—An "overlay" is a diagram normally composed of special military symbols drawn on transparent paper which has for its purpose the pictorial representation of military dispositions or situations at a given time. Its use is necessitated by the following facts: (1) We must conserve our maps because we shall never have an unlimited supply; (2) information coming from a great number of subordinate units in the form of overlays can easily be consolidated on the map of the higher unit and thus give a complete picture of that unit or of enemy activities; and (3) through the use of hastily-produced overlays, detailed information or instructions can be rapidly disseminated among subordinate units. This system reaches its peak of efficiency when orders are supplemented by operations overlays. A brief description of overlays will make their use within the capabilities of the new student as well as the person of considerable experience.

Remembering that an overlay is used for the purpose of conserving both time and effort, it is to be noted that no information is placed on the overlay which already appears on the original map. Information of the terrain or of man-made permanent features are only placed on an overlay when necessary for the correction of the map with which it is to be used, such as showing new buildings that have been erected or a shore line that has shifted since the time the map was originally compiled. Hence, there will normally be shown only military dispositions, field fortifications, establishments, schemes of maneuver, etc. These are all represented by means of authorized military symbols with the exception that when no approved symbol exists it is permissible to devise symbols so long as an explanation of them is given in the legend of the overlay.

In order that an overlay may be of use to a person other than the one constructing it, its purpose must be known and there must be some means of applying it accurately to any map similar to the one from which it was taken. This is done by giving the following information in the legend: Map or chart used, title, date of issue, scale; title of the organization submitting the overlay; place, date, and time of issue of the overlay; purpose of the overlay or designation of the order which it is to accompany. For exact application to another map it is necessary to inscribe at least two registration "ticks" on the overlay. These are in the form of small crosses which indicate the intersection of grid lines on the map. They are numbered with the corresponding numbers of the military grid, thus fixing the coordinates of two points on the overlay, and are normally placed near two diagonally opposite corners of the overlay. Maps, charts, and aerial photographs that have no grid will often be adapted to use in the Marine Corps. Overlays from these can be registered by showing the location of prominent features, such as buildings, road junctions, or a portion of the coast line. In conclusion, the student must remember that while another person might be able to divine information that has been omitted from the legend, an overlay is utterly useless if it does not contain marks of registration.

SECTION 2

THE MATHEMATICS OF MAP READING

9. **Introduction.**—A knowledge of elementary mathematics is sufficient for the requirements of map reading. This section contains those simple principles of elementary mathematics which should be reviewed prior to the study of this text.

10. **Fractions.**—a. A fraction is merely a way of indicating division. Thus the simple fraction $\frac{1}{4}$ means $1 \div 4$; $\frac{1}{62}$, $1 \div 62$; and $\frac{41}{13}$, $41 \div 13$. Thus the fraction sign (—) indicates division.

b. Complex fractions consist of a whole number over a fraction $\frac{2}{\frac{1}{4}}$, a fraction over a whole number $\frac{\frac{1}{6}}{5}$, or of a fraction over a fraction $\frac{\frac{3}{4}}{\frac{4}{7}}$. Complex fractions can always be reduced to ordinary fractional form by merely performing the division indicated. First, the complex fraction is written so as to show division; thus, $\frac{\frac{3}{4}}{\frac{4}{7}} = \frac{3}{4} \div \frac{4}{7}$. Then the denominator, (the lower section of the fraction) is inverted (turned upside down), thus $\frac{4}{7}$ becomes $\frac{7}{4}$. The numerator

(upper section) of the fraction is then multiplied by the inverted denominator (lower section); thus $\frac{3}{4} \times \frac{7}{4} = \frac{3 \times 7}{4 \times 4} = \frac{21}{16}$, thus our answer $\frac{21}{16}$ is the simple fractional form equal to the complex fraction $\dfrac{\frac{3}{4}}{\frac{4}{7}}$.

Examples of complex fractions reduced to simple form:

$$\frac{2}{\frac{1}{4}} = 2 \div \frac{1}{4} = 2 \times \frac{4}{1} = \frac{8}{1} = 8.$$

(A number divided by one equals the number, thus $\frac{8}{1} = 8$).

$$\frac{\frac{1}{6}}{5} = \frac{1}{6} \div 5 = \frac{1}{6} \times \frac{1}{5} = \frac{1}{6 \times 5} = \frac{1}{30}$$

(To invert a whole number, write it as a fraction with one as the numerator, thus 5 inverted $= \frac{1}{5}$).

$$\frac{\frac{1}{6227}}{\frac{1}{4283}} = \frac{1}{6227} \div \frac{1}{4283} = \frac{1}{6227} \times \frac{4283}{1} = \frac{4283}{6227}$$

c. The value of a fraction remains unchanged if both the numerator and the denominator are multiplied or divided by the same number, e.g.

$$\frac{1}{4} = \frac{1 \times 2}{4 \times 2} = \frac{2}{8} = \frac{2 \div 2}{8 \div 2} = \frac{1}{4}; \quad \frac{1}{4} = \frac{1 \div 3}{4 \div 3} = \frac{\frac{1}{3}}{\frac{4}{3}} = \frac{1}{3} \times \frac{3}{4} = \frac{3}{12} = \frac{3 \div 3}{12 \div 3} = \frac{1}{4}$$

Thus, if you wish to reduce a fraction to a form in which its numerator is one, divide both the numerator and the denominator by the numerator, e.g., to reduce $\frac{4}{24}$ to a fraction with a numerator of one: $\frac{4}{24} = \frac{4 \div 4}{24 \div 4} = \frac{1}{6}$.

11. Ratio and Proportion.—a. Fractions may be used to represent the ratio between two things. If one object weighs one-half as much as another, the ratio between their two weights is 1:2 (read "1 to 2"). This ration 1:2 may also be written as the fraction $\frac{1}{2}$.

b. Ratio is also used when speaking of distance travelled. If one says that he has gone $\frac{3}{4}$ of the way from A to B, the ratio of the distance he has come to the total distance is 3:4. The ratio of the distance he has come to the remaining distance is 3:1.

12. Fractional Equations.—a. Map reading often involves simple fractional equations in which the value of an unknown can be found by applying certain simple rules. For example (solving for the unknown "X"): $\frac{X}{3} = \frac{2}{5}$.

To solve for X it is necessary merely to use the same principles discussed in paragraph 10b, i.e., complex fractions.

$$\frac{X}{3} = \frac{2}{5} \qquad \text{then} \qquad \frac{\frac{X}{3}}{\frac{2}{5}} = \frac{\frac{2}{5}}{\frac{2}{5}}$$

$$\frac{X}{3} \times \frac{5}{2} = \frac{2}{5} \times \frac{5}{2}$$

$$\frac{5X}{6} = \frac{\cancel{10}}{\cancel{10}} = 1$$

$$\frac{\cancel{6}(5X)}{\cancel{6}} = 6\ (1)$$

$$5X = 6$$

$$\frac{\cancel{5}X}{\cancel{5}} = \frac{6}{5} \qquad X = \frac{6}{5}$$

In solving for X by the method shown above we have, in effect, **cross-multiplied.** The procedure of cross-multiplication is as follows: Multiply the numerator of each side of the equation by the denominator of the other side of the equation. Set these two products equal to each other and solve for the unknown (X).

For example:

$$\frac{X}{3} \times \frac{2}{5}$$

$$5X = 6$$

$$\frac{\cancel{5}X}{\cancel{5}} = \frac{6}{5}$$

$$X = \frac{6}{5}$$

13. **Decimals.**—a. Decimals are a means of writing fractions without using the fraction sign (—). Any fraction may be reduced to decimal form by direct division of the numerator by the denominator, e.g.

$$\frac{1}{4} = 4\overline{)\ 1.00} = .25$$

$$\frac{5}{2} = 2\overline{)\ 5.0} = 2.5$$

b. Decimals are added and subtracted just as are whole numbers, except that the decimal point must be placed directly under all decimal points above it, e.g.

Addition		Subtraction	
2.56	21.01	69.000	.706
.004	100.0761	− 7.001	−.032
66.	.32	61.999	.674
+ .01	+ 9.		
68.574	130.4061		

c. Multiplication of decimals is performed just as though there were no decimal point present. Then the answer is pointed off a number of places (starting at the right and counting left) equal to the total number of decimal places in the two numbers being multiplied together, e.g.

```
   16.009   (three decimal places)
     4.12   (two decimal places)
  -------
    32018
   16009
  64036
 --------
 65.95708   (3 + 2 = 5 decimal places)

    6.012   (three decimal places)
       12   (no decimal places)
  -------
    12024
    6012
  -------
   72.144   (3 + 0 = 3 decimal places)
```

d. Before division can be performed on decimals, the decimal in the divisor must be moved entirely to the right hand side of that number, thus

```
2.25.)45.00.
```

The decimal in the dividend must be moved to the right the same number of places (as shown above—in some cases zeros must be added on the right of the number). This moving of the decimal really amounts to multiplying both numbers by some multiple of ten (in the above case by 100).

After moving the decimal, ordinary division is performed:

```
          20.
      -------
2.25.)45.00.
      45 0
      ----
        00
```

The decimal in the answer is placed directly above the decimal in the dividend.

Other Examples:

```
           359.4                               .00002
      .006.)2.156.4                 71.2.).0.01424
           1 8                                 1424
            35                                    0
            30
             56
             54
              24
              24
               0
```

14. **Parallel Lines.**—Parallel lines play a large part in map reading. Since both the geographic and military grid systems of coordinates (means of location) are based on the properties of parallel lines, certain of these properties should be understood:

a. Parallel lines are lines in the same plane (two dimensional surface) which will never intersect. Thus the shortest (or perpendicular) distance between parallels is constant.

b. Angles formed by the intersection of a line with a series of parallels have certain definite relationships:

In figure 2, we have the parallel lines ab, cd, and ef, and xy is any straight line cutting these parallel lines.

$$\angle C = \angle E;\ \angle D = \angle F;\ \angle G = \angle I;\ \angle H = \angle K$$

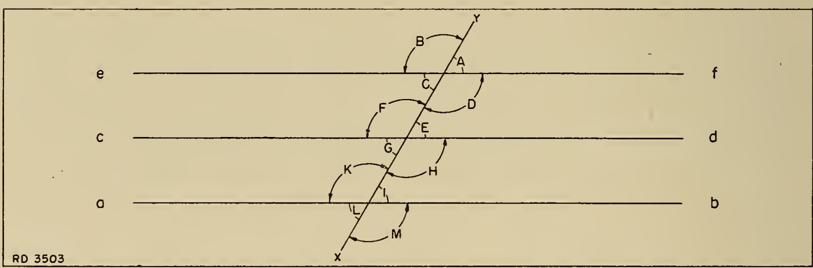

Figure 2.—Angles formed by a line intersecting parallel lines.

(2) The alternate exterior angles are equal.

$$\angle A = \angle G;\ \angle B = \angle H;\ \angle F = \angle M;\ \angle E = \angle L$$

(3) The corresponding angles are equal.

$$\angle B = \angle F = \angle K; \quad \angle A = \angle E = \angle I$$
$$\angle C = \angle G = \angle L;\ \angle D = \angle H = \angle M$$

15. The Circle and Its Uses.—a. Since the circle is one of the most important geometric figures in map reading, its component parts and their nomenclature and relationship must be understood.

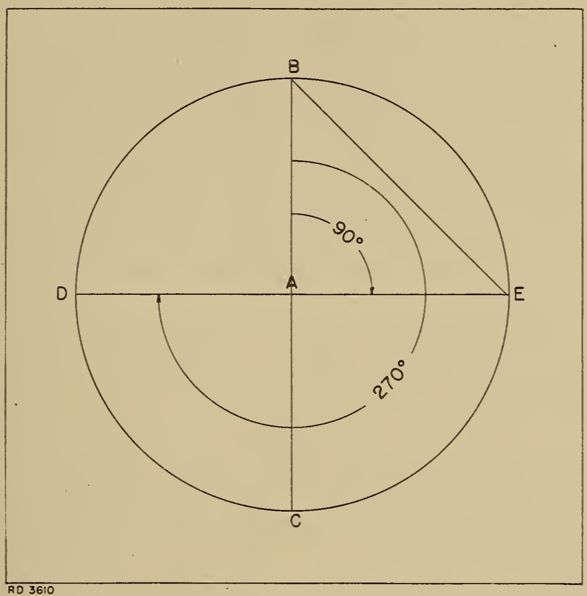

Figure 3.—The Circle.

b. In the above figure, point A is the center of the circle. The line AB is the radius (r) of the circle, or the distance from the center to any point on the circle. The line BAC is the diameter (d) of the circle and is equal to two radii $(d = 2r)$.

If the center A remains in place and the radius AB swings in a clockwise direction (the direction in which the hands of a clock move) about A, then the point B will trace the rim or circumference BECD of the circle. It has been found by measurement that the circumference (C) is equal to πd. $(\pi = 3.14 +)$

$C = \pi d$

since $d = 2r$

then $C = 2\pi r$

c. The circumference is a linear measure and, as has been shown, is dependent on the length of the radius. A circle can also be measured by angular units. The unit of angular measure is the degree, which is independent of the length of the radius. By definition: Any circle = 360°

1° (degree) = 60′ (minutes)
1′ (minute) = 60″ (seconds)

d. Whenever two lines intersect at a point an angle (∠) is formed. To measure the angle it is assumed that the angle is a segment of a circle and its measurement is expressed in degrees. In military map reading this measurement is always made in a **clockwise** direction.

For example: In Figure 3, line BA and EA intersect at A. This forms the angle BAE (∠BAE). The angular measurement from BA to EA is shown as 90°. (A 90° angle is known as a right angle.)

In the same figure, the angle between BA and DA would be 270°, since angles are always measured in a clockwise direction on military maps.

e. In Figure 3, the segment of the circumference cut off by the ∠ BAE is called the arc BE (BE). The straight line BE is the chord (BE) of the arc BE. As the size of the angle decreases, the length of the chord approaches the length of the arc so that for very small angles the length of both is practically the same.

f. For military use another unit of angular measure besides the degree is often used because of its simplicity. It is very important in all phases of gunnery and as gunnery and map reading are closely linked, its uses should be known and understood. This unit is the **mil.**

A **true mil** is the angle formed by two radii 1000 units long and an arc of 1 unit or as it is generally stated: the angle subtended by an arc of 1 unit and a radius of 1000 units. In this case one might say that an object one yard long and 1000 yards away from an observer forms an angle of 1 mil at his eye.

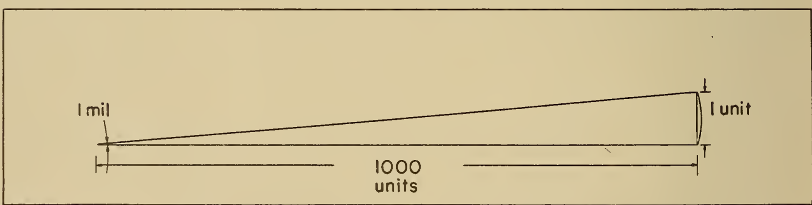

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Figure 4.—Diagram of 1 Mil.

A circle is arbitrarily assumed to contain 6400 mils (this circular or military mil is slightly smaller than a true mil, but the difference is so small that for all practical purposes they are considered to be identical).

An angle measured is mils is measured in a clockwise direction, just as is an angle measured in degrees.

16. **Working Problems.**—a. Most errors in solving problems result from carelessness on the part of the student. Such errors may have consequences that are serious and far reaching. They cannot be tolerated. Large errors, such as misplacing the decimal point, seem to be more common than small ones. To avoid errors, **check your results.** There is usually time for at least a rough check. Going back over the work step by step does not give a satisfactory check. It is better to use a different method, an independent one if possible.

b. The student must also remember to reduce all distances or quantities in each problem to the same unit. For instance, mils and degrees cannot be added together without first converting one of the two quantities to the other type of unit.

17. **Navy Time.**—The Navy and Marine Corps use the Continental or 24 hour clock system of time. This eliminates the confusion of a.m. and p.m., morning and evening. The time is always expressed as a 4-figured number from 0001 to 2400. Midnight is 2400, high noon 1200. The first two digits are the hours and run from 00 to 24. The second two digits are the minutes and run from 00 to 60.

To convert civilian time to Navy time:

a. If a.m. (morning) and before 10 o'clock, prefix a zero to the hours and minutes to give a 4-figured number; e.g., 7:45 a.m. becomes 0745.

b. If p.m. (afternoon) add 1200 to the hours and minutes; e.g., 4:15 p.m. becomes 1615.

No colons, symbols or breaks of any kind are used to separate the hours from the minutes.

When adding or subtracting Navy time it is well to separate the hours and minutes slightly.

Example: A column of troops left the barracks at 0900, marched for 2 hours and 45 minutes, had an hour for chow, then marched for 3 hours and 30 minutes. At what time did they reach their destination?

09 00	Time of departure
2 45	First marching period
1 00	Chow time
3 30	Second marching period
15 75	Total

The above figure indicates 15 hours and 75 minutes total time.

Since 75 minutes equals 1 hour and fifteen minutes, the time of arrival is 1615.

$$\begin{array}{r} 15\ 00 \\ 1\ 15 \\ \hline 16\ 15 \end{array} = \textbf{Time of arrival.}$$

NOTE: No matter how small the fraction of a minute may be, in computing time it becomes the next larger whole minute; e.g., 1614 1/10 or 1614.1 becomes 1615.

18. Table of Equivalents.—

Linear Measure:

1 foot (′) = 12 inches (″).
1 yard = 3 feet = 36 inches.
1 statute mile = 1,760 yards = 5,280 feet = 63,360 inches.
1 meter = 1.094 yards = 39.37 inches.
1 kilometer = 1,000 meters = 1,094 yards = .62 miles.
1 mile = 1.61 kilometers.

Angular Measure:

360 degrees (°) = 1 circle = 6400 mils.
1° = 17.8 mils.
1 mil = .056°.
1° = 60 minutes (′).
1′ = 60 seconds (″).

Geographic or Nautical Measure:

1 nautical mile = 6080.20 feet = 1.1516 statute miles.
60 nautical miles = 1 degree (°) at the equator.
1 knot = 1 nautical mile per hour.
1 fathom = 6 feet (depth of sea).

Surveyor's Measure:

1 link (li.) = 7.92 inches.
100 links = 1 chain (ch.) = 66 feet.
10 chains = 1 furlong = 660 feet.
80 chains = 1 mile.
(The engineer's chain is 100 feet long with links 1 foot long.)

SECTION 3

CONVENTIONAL SIGNS AND MILITARY SYMBOLS

19. Conventional Signs.—a. Map makers have devised a common set of signs which to the map reader have a definite meaning. For instance, there are signs for a house, for a road, for a bridge, etc. These are called conventional signs. Some of them look enough like the object they are intended to represent to be easily recognized such as conventional signs for lakes or bridges. The meanings of some are not so obvious and must be learned just as new words are learned. Complete lists of conventional signs authorized for use on military maps are published in FM 21-30. The most commonly used conventional signs are shown in Figures 5a & 5b and also on the "Sheet of Standard Symbols". These need not be memorized, but the student should study them from time to time until familiar with the forms.

b. Conventional signs vary in size with the scale of maps. On small scale maps comparatively few objects can be shown and the signs are reduced to their most elementary form. As the scale is increased more objects can be represented.

c. Locations of some objects are shown with more accuracy than others due to manner in which the topographer and map draftsman work. Some of these in order of accuracy are:

(1) Triangulation stations.

(2) Surveying monuments.

(3) Railroads and canals.

(4) Important bridges.

(5) Main roads.

(6) Isolated buildings on main roads, including churches and schoolhouses.

(7) Secondary roads.

(8) Streams, contours, and woodlands, cleared areas, etc. In choosing landmarks for determining location, these relative values should be kept in mind.

d. When colors are used for War Department maps, they are used as follows: black for works of man and for grid lines; brown for contours, cuts, and fills; blue for water; green for woods and vegetation; red to indicate road conditions.

e. Occasionally conventional signs will be found that are not given in FM 21-30, but these should be indicated in the margin of the map with such explanatory notes as are necessary.

COMMON CONVENTIONAL SIGNS

Roads, Improved
Roads, Unimproved
Trails, Good
Trails, Poor Pack or Foot
Railroads (single track)
Railroads (double track)
Railroads (narrow gauge)
Tunnels (railroad)
Bridges (general)
Telegraph or Telephone Line
Power Transmission Line
Buildings in General
Church or Place of Worship
Schoolhouse
Cemetery
Fort
Fences (stone)
Fences (worm)
Fences (wire)
Triangulation Station
Bench Mark (and elevation)
Combined Triangulation Station and Bench Mark (with elevation)

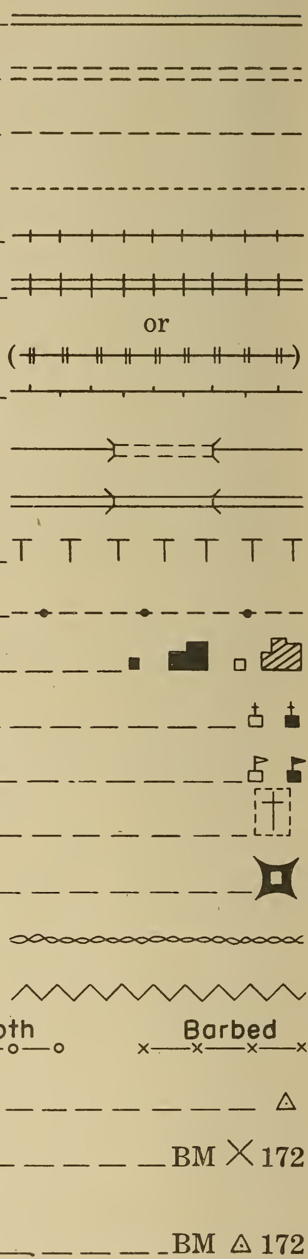


Figure 5a.—Common Conventional Signs.

Figure 5b.—Common conventional signs.

20. **Military Symbols.**—a. A conventional sign indicates various types of terrain features. Military symbols have been developed to represent various types of military organizations, activities, and installations. These symbols are used to indicate size and identity of various units and installations, type and location of supporting weapons, and necessary lines and boundaries for an operation. A material saving of time in giving orders for military operations may be achieved by using military symbols to outline operations on a map or a map substitute.

b. The text "Military Symbols and Abbreviations" lists the standard military symbols authorized for the Marine Corps, and shows how they are derived.

SECTION 4

MAP MEASUREMENTS

21. **Scales.**—In map reading the scale of the map is a first consideration. The scale is the relation between measurements on the map and actual distances on the ground. The scale of a map is expressed in one or more of the following ways:

a. **Words and figures.**—Actual equivalents given in words and figures as 3 inches equal 1 mile means that 3 inches on the map equals 1 mile on the ground; 1 inch equals 200 feet means that 1 inch on the map equals 200 feet on the ground.

b. **Representative fraction.**—The scale of a map may be shown as a representative fraction (usually abbreviated to RF). This fraction expresses the ratio between a given distance on a map and the corresponding distance on the ground. The RF is shown thus: 1:63,360 or $\frac{1}{63,360}$ which means one unit of distance on the map equals 63,360 such units of distance on the ground. The same kind of units of distance measured from the map must be applied to distances on the ground. For instance, in the RF shown above, 1 inch on the map equals 63,360 inches (or 1 mile) on the ground and 1 foot on the map equals 63,360 feet (or 12 miles) on the ground. The greater the denominator the smaller the scale; a 1:20,000 map is a large-scale map, and a 1:1,000,000 is a small-scale map.

c. **Graphic scales.**—The figure resembling a small ruler printed on the map is also called a scale. It is divided into parts, each division being marked not with its actual length but with the distance each length represents on the ground. Usually there will be one part graduated into mile units and fractions of a mile. The other part is graduated in yards for more exact measurements of ranges, frontages, and depths. Many maps also show the kilometer scale. Each graphic scale consists of a primary scale to the right of zero, and an extension to the left of zero. The extension consists of one primary unit of the graphic scale subdivided into appropriate fractions. Typical graphical scales as used on American maps can be seen on the lower margin of Figure 6. The scale in Figure 6 has 1,000-yard units for the primary scale and ten 100-yard units for the extension.

22. **Distance.**—Once the scale of the map is known, distances on the ground which are represented on the map can be determined. Even though the scale is given in words and figures or as an RF, some sort of graphic scale is usually

necessary. The graphic scale is the most accurate and the most common means of determining distances from a map. Some methods of employing the graphic scale follow:

a. To find distance between two points on map.—

(1) Lay the straight edge of a piece of paper or other material along two points on the map, mark the location of the two points on the straight edge by using short straight marks called "ticks" at right angles to the edge of a paper.

(2) Take the marked straightedge and place it below the graphic scale on the margin of the map to determine the ground distance required. Where the distance is greater than the length of the graphic scale, apply the primary scale one or more times until the remainder can be measured as explained above. Distances between the smallest divisions of the scale are estimated.

(3) **Example.**—(a) **Problem.**—Figure 6 shows a portion of a 1:20,000 map. Required, to find actual distance on the ground between the house at A and the house at B.

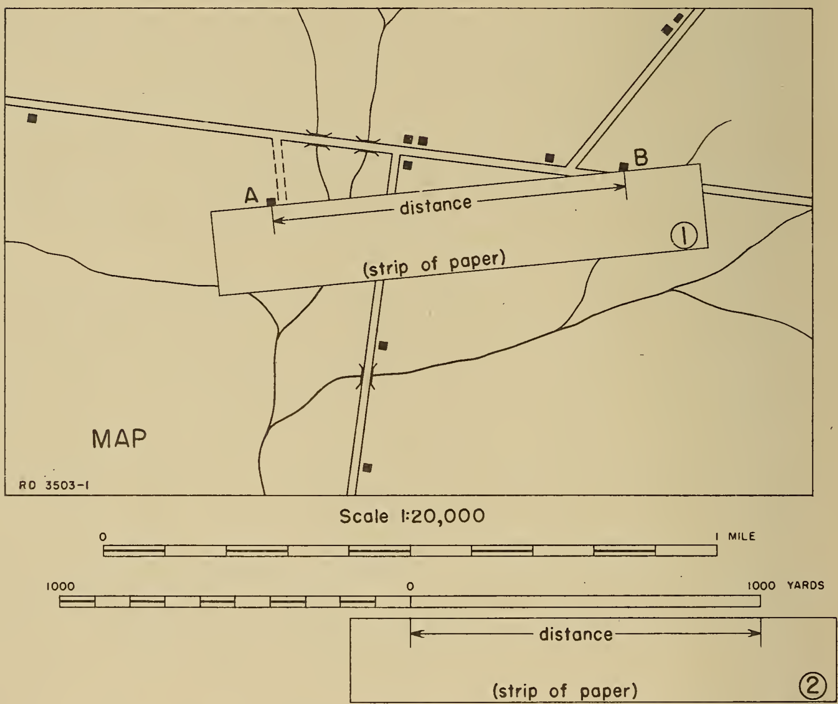


Figure 6.—Using graphic scale to measure distance.

(b) **Solution.**—Lay the straightedge of a strip of paper along A and B on the map and make tick marks. Take the strip of paper and lay its marked edge along the graphic scale on the margin of the map as shown in Figure 6(2). The required distance between ticks is read directly from the scale as 1,000 yards.

b. **To find distance along irregular line of map.**—It is sometimes necessary to measure the distance along irregular lines on a map such as a stream or a winding road. There are several ways to do this, the two most satisfactory being the "paper strip" and the "transparent paper" methods.

(1) **Paper strip method.**—(See Figure 7). Take a straight edged piece of paper, lay it at the starting point of the curved distance to be followed and make a tick mark across the map and paper. At every curve in the course make another tick mark, turn the paper so the edge again lies along the course in question and register the last tick marks. Continue this until the distance is completely measured. The final position of the paper strip is illustrated in Figure 7. The important thing is to have the tick mark on the paper strip accurately placed and equal to the corresponding tick mark on the map, so that the true distance is marked off on the paper strip. The paper strip is then applied to the graphic scale of the desired unit as in Figure 6 (2) and the ground distance is read.

Caution: Graphic scales are generally shown in miles, yards and kilometers. Care must be exercised in selecting the proper graphic scale in the unit of measure desired.

(2) **Transparent paper method.**—By means of a straightedge and a sharp pencil draw a long straight line generally down the center of any transparent piece of paper. For a starting point, draw a straight line (tick) perpendicular to and near one end of the first line. Lay the paper on the road with the starting tick over A so that the long line extends through 1. Place the pencil point at 1 and pivot the paper until the long line lies along the course 1-2. Place the pencil point at 2 and pivot the paper as before. Continue until the long line lies along course 4-b. Mark the position of B by a tick on the long line. Measure the distance along the graphic scale as described above.

23. Time.—a. **Conversion of march time to distance.**—It will often be necessary to determine the distance a column can march in a given period of time. The distance is the product of the time in hours multiplied by the hourly rate of march. For example, a motorized unit averaging 30 miles per hour can cover $4 \times 30 = 120$ miles in 4 hours. This whole distance is plotted on the edge of a strip of paper by means of the mile graphic scale. Then the distance may be laid off along the straight portions of the road by marking ticks for each change of direction along the measured portion of the strip of paper, reversing the methods shown in paragraph 22. Thus the position of the head of the column at the end of any given time may be determined.

The Humphrey Time and Space Scale is devised for rapid computation of rates of march from 1½ to 15 miles per hour.

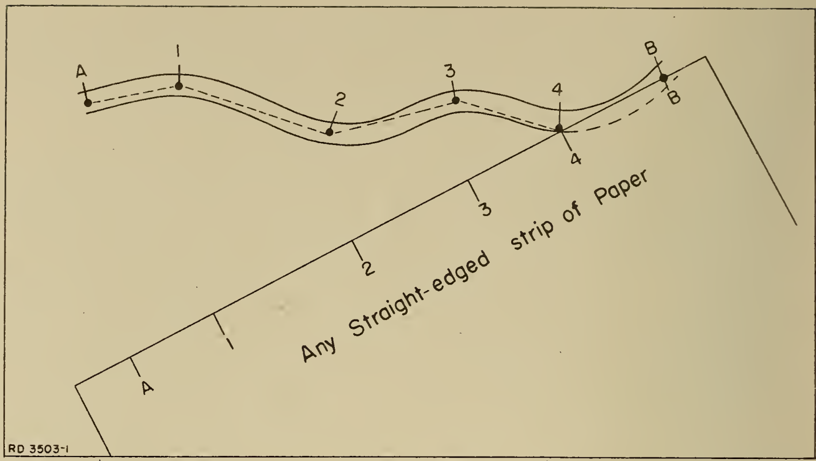


Figure 7.—Measuring distance along a winding road.

b. **Conversion of distance to march time.**—To determine how long it will take to move troops from one point to another, the distance between the two points is taken as above from any suitable map. The distance divided by the hourly rate of march gives the time required to move the troops. The habitual daytime rate of march for foot troops, making allowance for customary halts, averages 2½ miles per hour. For example, the time to march foot troops a distance found to be 15 miles on the map is 15 divided by 2.5, or 6 hours.

24. **Relation between Distances and Areas on Maps of Different Scales.**—Figure 8 shows at a reduced scale an identical area of ground represented on maps of three different scales; that is, 1:5,000, 1:10,000, and 1:20,000. A, B, C, and D are points on the ground. A′ B′ on a map of scale 1:5,000 is just twice as long as AB on a map of scale 1:10,000. The area of the map A′ B′ C′ D′ at scale 1:5,000 is just four times the size of the same area at scale 1:10,000. Conversely, A″ B″ on a map of scale 1:20,000 is just one-half as long as AB on a map of scale 1:10,000 and the area A″ B″ C″ D″ is one-fourth the size of ABCD. These relationships may be stated as follows:

a. **Distances.**—Distances on different maps vary directly as the representative fractions of the maps and inversely as the denominators of their respective fractions, thus (Figure 8):

$$\frac{AB}{A'\,B'} = \frac{RF}{R'F'} = \frac{\frac{1}{10{,}000}}{\frac{1}{5{,}000}} = \frac{5{,}000}{10{,}000} = \frac{1}{2}$$

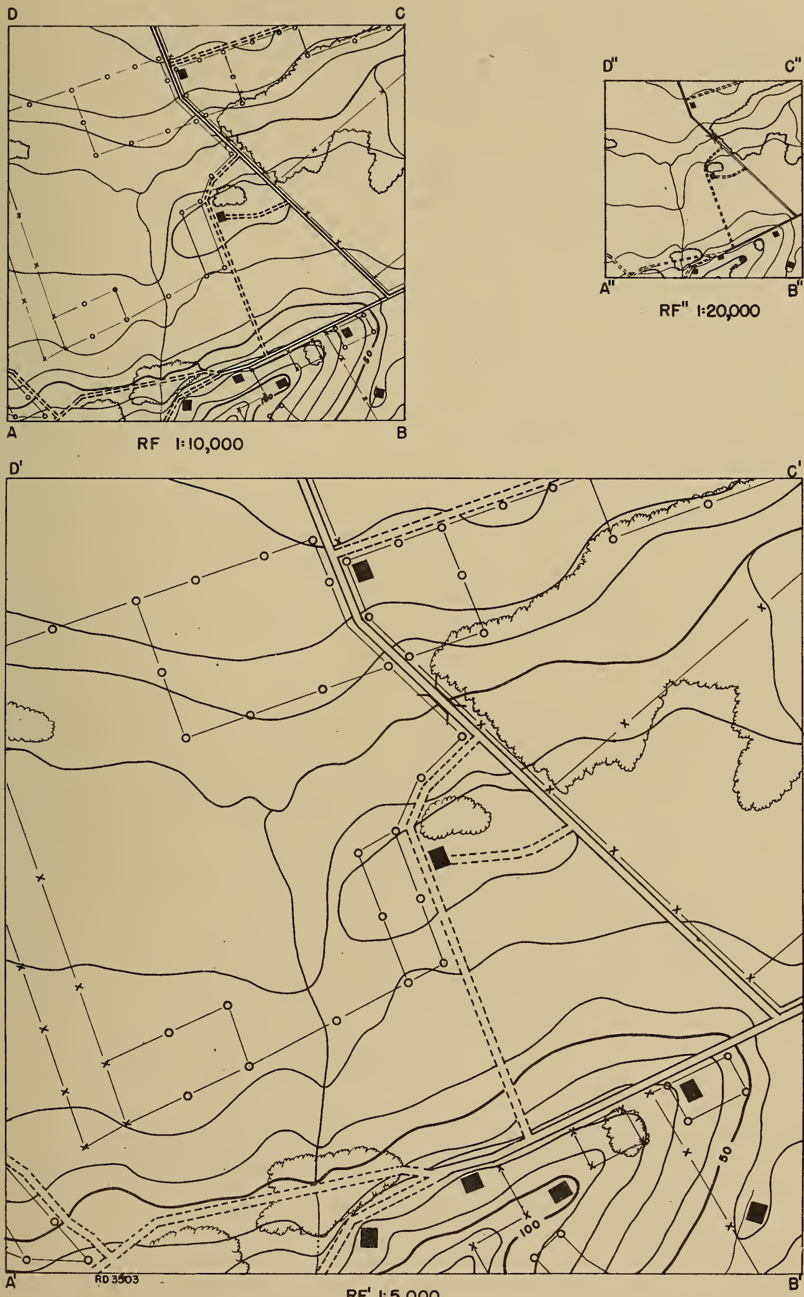


Figure 8.—Relation between distances and areas on maps of different scale. (Scales of maps shown above have been reduced in printing.)

b. **Areas.**—Areas on different maps vary directly as the squares of the representative fractions of the maps and inversely as the squares of the denominators of their respective fractions, thus (Figure 8):

$$\frac{ABCD}{A'B'C'D'} = \frac{(RF)^2}{(RF')^2} = \frac{\left[\frac{1}{10{,}000}\right]^2}{\left[\frac{1}{5{,}000}\right]^2} = \frac{(5{,}000)^2}{(10{,}000)^2} = \frac{1}{4}$$

25. **Determination of Scale of Map and Construction of Graphic Scale.**—It is important that the user of a map be able to determine the RF of a map when in the field and readily construct a suitable graphic scale for use in the event that the scale data are missing from the map. The procedure is as follows:

a. **Determination of scale.**—The scale of a map may be determined from known distance on the ground, or from scaled distance on another map of known scale.

(1) **By measurement of distance between two points on ground.**—(a) Locate two objects on the ground which can be identified on the map, such as bridges, houses, etc.

(b) Estimate, stride, or measure on the ground in some manner, the distance between the selected points, and convert into inches. (The method of measuring should depend on accuracy required, time available, etc.)

(c) Measure in inches the distance on the map between the two points selected.

(d) Determine the scale from the relation—

$$RF = \frac{MD}{GD} \quad \left(RF = \frac{\text{distance on map in inches}}{\text{distance on ground in inches}}\right)$$

This expression, when reduced to a fraction the numerator of which is unity, becomes

$$RF = \frac{1}{\frac{GD}{MD}} \quad \left(RF = \frac{1}{\left(\frac{\text{distance on ground in inches}}{\text{distance on map in inches}}\right)}\right)$$

NOTE: Distances may be expressed in any unit of measurement provided the same is used for both map and ground distances.
Example: Map distance between two points = 3 inches; ground distance between corresponding points = 5,208.3 yards.

$$RF = \frac{1}{\left(\frac{5{,}208.3 \times 36 \text{ inches}}{3 \text{ inches}}\right)} = \frac{1}{62{,}500}$$

(2) **By measurement between two points on map of known scale.**—(a) Locate two objects on map of known scale which can be identified on the map the scale of which is to be determined.

(b) Scale from both maps the distances between the points in the same unit of measurement (inches).

(c) Determine the scale of the map by one of the two methods given below:

1. Convert distance on map of known scale to distance on the ground, and solve as in (1) above, or

2. Determine scale from the relation—

$$\frac{\text{RF of the map}}{\text{RF of map of known scale}} = \frac{\text{distance on the map}}{\text{distance on the map of known scale}}$$

Example: Distance between two points on the map of unknown scale = 8 inches.

Distance between corresponding points on a map of 1:20,000 scale = 4 inches.

$$\frac{\text{RF}}{\frac{1}{20{,}000}} = \frac{8}{4}$$

$$\text{RF} = \frac{8}{4} \times \frac{1}{20{,}000} = \frac{1}{20{,}000 \times \left[\frac{4}{8}\right]} = \frac{1}{10{,}000}$$

It is seen from the above that the denominator of the RF of the map (10,000) is obtained by multiplying the denominator of the RF of the map of known scale (20,000) by the distance measured on the map (4) and dividing by the distance measured on the map the scale of which is sought (8).

b. **To construct a graphic scale** (Figure 9a).—(1) Suppose it is desired to construct a graphic scale to read 1,000 yards for use on a map with an RF of 1:10,000. The first step is to find the total length of the scale by application of the formula $\text{RF} = \frac{\text{MD}}{\text{GD}}$

MD = map distance = total length of scale in inches.
GD = ground distance = 1,000 yards = 36,000 inches.
RF = 1:10,000.

$$\frac{1}{10{,}000} = \frac{\text{MD}}{36{,}000}$$

$$10{,}000 \text{ MD} = 36{,}000.$$

MD = 3.60 inches (total length of scale representing 1,000 yards to an RF of 1:10,000.)

The next step is to lay off a line the total length of the graphic scale and then subdivide it into the desired number of divisions. In this case it is desirable to divide the scale into 100 yard divisions, with the leftmost 100 yard division again subdivided to 20 yard divisions to form an extension or secondary scale. If the total length of the scale was such that it was conveniently divisible by the use of a ruler, we would divide it in that way, (for example, if the total length was 5 inches, each 100 yard division would naturally be .5 or ½ inch long which is easily measured) but if the total length is not easily divisible as in the case of 3.60 inches a geometric means of division is used.

(2) **Geometric division of a line.**—(a) Line ab (Figure 9a) is 3.60 inches long. We wish to divide it into 10 equal parts.

(b) Draw a line from a at an acute angle from line ab. This is line ab′. The length of ab′ should be such that it is easily divisible into the total desired number of divisions. In this case 10 divisions are desired so a 3-inch line is drawn. With an engineer's scale this can be divided into 10 divisions .3 inch long.

(c) Connect b and b′ with a construction line (line bb′).

(d) Draw parallels to bb′ from ab′ to ab. These parallels will divide ab into 10 equal parts.

(e) The extension at the left of the scale can be further divided in the same manner.

(If the method of constructing parallels is not understood see Figure 9b. A right angle and a straight edge are the tools required. The engineer's scale and military protractor are the most convenient.)

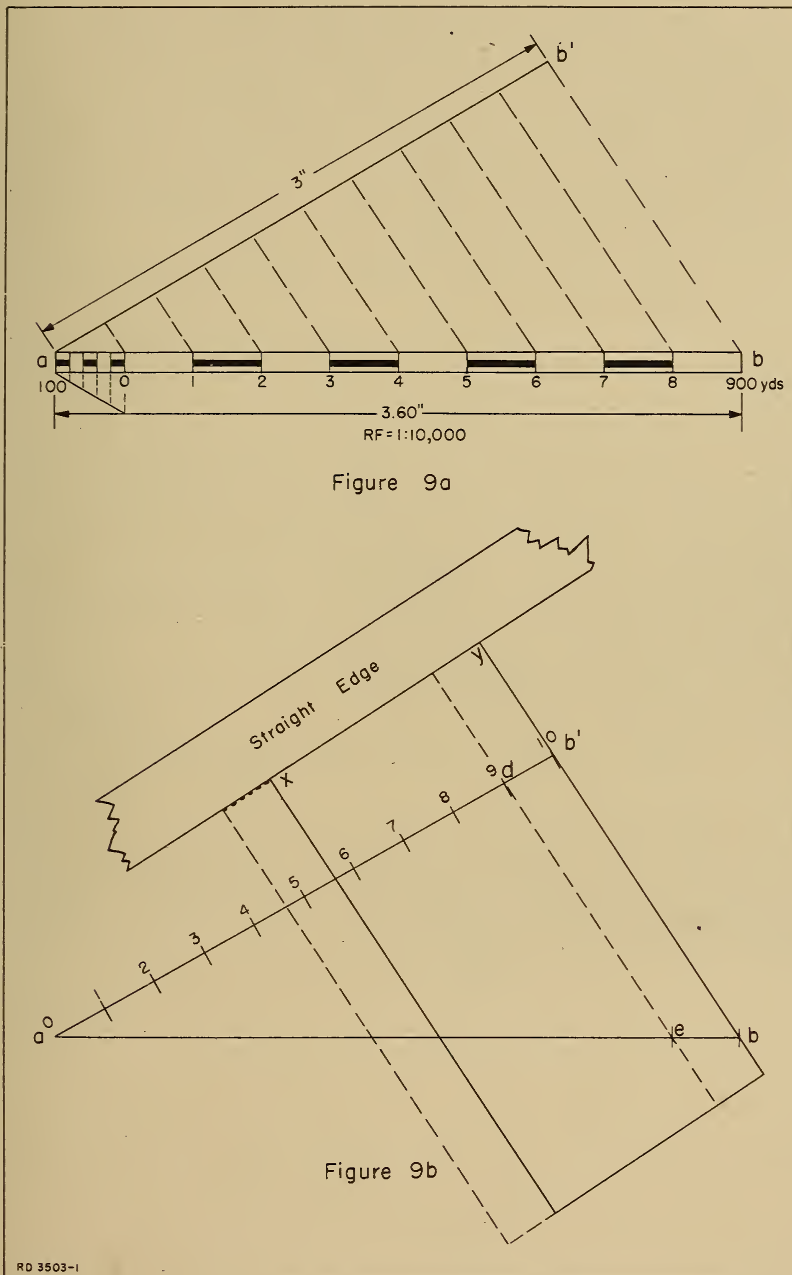
(a) Lay the rectangle so it connects bb′.

(b) Place the straight edge along the upper edge of the rectangle (xy).

(c) Holding the straight edge fast, slide the rectangle to point 9 and draw de; de will be parallel to bb′.

(d) Continue until ab is totally divided.

(3) Another method not so accurate as the above but simpler and quite satisfactory for practical purposes is to compute the length of one 100-yard graduation (or any other suitable division) of the primary scale and then apply that as many times as necessary along a line. For example, in the case of the map whose RF was determined as 1:2,769, the length of a 100-yard interval of the scale would be $\frac{3,600}{2,769} = 1.3$ inches, approximately. Point off this distance as many times as 100-yard graduations are required for the primary scale, subdividing the left interval as the extension.



Figures 9a & 9b.—Construction of graphic scales.

26. Time-Distance Scales.—In solving tactical problems or in planning military operations on maps, time-distance scales frequently prove time-saving devices of great usefulness. A time-distance scale is a scale whose graduations are time intervals of distance to the scale of the map at a given rate of movement (fig. 10). Suppose that a time-distance scale graduated in hours and minutes of time at a given marching rate, is desired for use on a topographic map 1:62,500. To construct such a scale, the procedure is as follows:

a. (1) In 1 hour, infantry marches $2\frac{1}{2}$ miles or $2\frac{1}{2} \times 63{,}360 = 158{,}400$ inches.

(2) 158,400 inches on the ground $= \dfrac{158{,}400}{62{,}500} = 2.53$ inches on a map whose scale is 1:62,500.

(3) On a suitable strip of paper along a straight line ab (Figure 10), lay off as many 1-hour intervals of 2.53 inches each as may be desired in the scale. Subdivide the left interval on the scale extension into 1-minute, 5-minute (used in Figure 10), or 10-minute graduations, depending on the least reading desired; mark the graduations appropriately. On the scale, indicate the RF of the map to which the scale applies and the marching rate to which constructed.

b. (1) In 1 hour, a motor column marches 30 miles or $30 \times 63{,}360 = 1{,}900{,}800$ inches.

(2) 1,900,800 inches on the ground $= \dfrac{1{,}900{,}800}{62{,}500} =$ 30.41 inches on the map.

This shows why operations for units with such rates of march would ordinarily be planned on smaller scale maps. Hence the time-distance scale for a motor column is shown in Figure 10 for a 1:500,000 map, making a 1-hour march equal to 3.80 inches on the map.

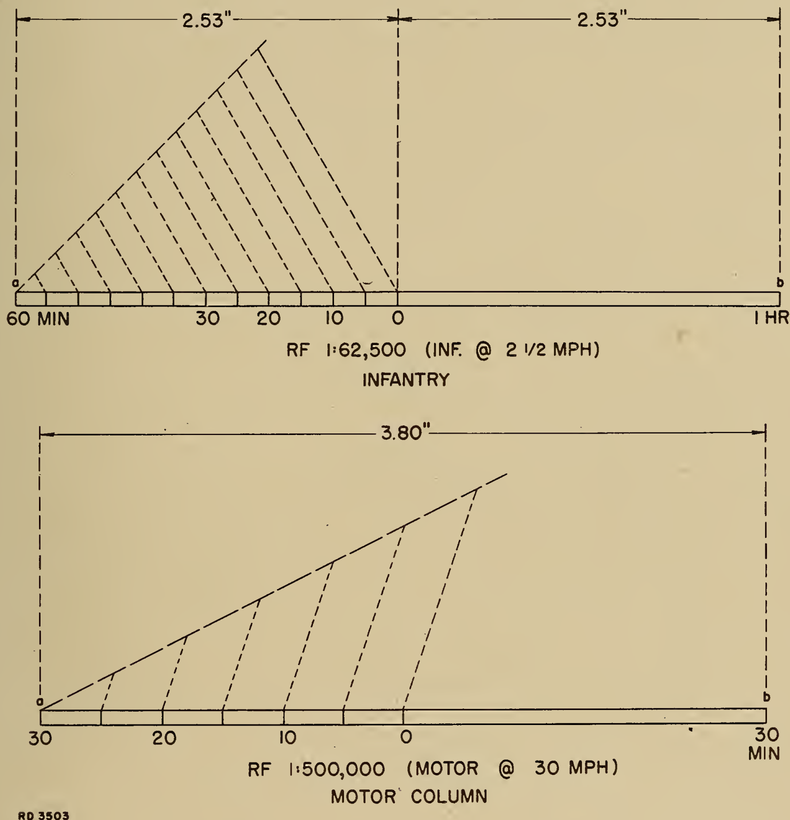


Figure 10.—Time—Distance scales.

SECTION 5

DIRECTION

27. **Need For Direction.**—To locate objects, both direction and distance are needed. For example, an object can be located by telling how far away and in what direction it is from a given point. Most persons are familiar with the established geographic terms, north, south, east, and west. These are the directions that are indicated by the common military watch compass.

28. **Units of Angular Measure.—a. General.**—Angles may be measured in degrees, minutes, and seconds, or in mils (see Figure 11). Normally, only persons in artillery or heavy weapons units have to use the mil since their fire control instruments are generally graduated in mils rather than in degrees. Other personnel usually use degrees, minutes, and seconds.

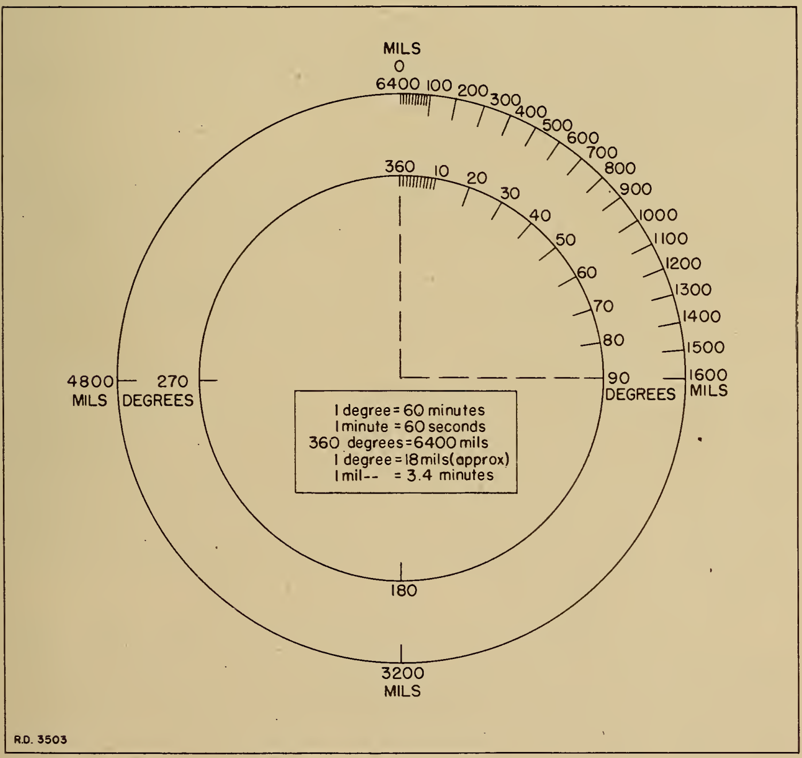


Figure 11.—Units of measurement.

b. **Angles.—(1) In degrees, minutes, and seconds.—** If the circumference of a circle is divided into 360 equal parts by lines drawn from the center to the circumference, the angle at the center between any two adjacent lines is one degree. There are 60 minutes in a degree, and 60 seconds in a minute. Thus:

60″ (seconds) = 1′ (minute)
60′ (minutes) = 1° (degree)
360° (degrees) = 1 circle or a circumference.

Angles are written—137°45′23″.

(2) **In Mils.—**If the circumference of a circle is divided into 6400 equal parts by lines from the center to the circumference, the angle at the center between any two adjacent lines is one circular or military mil. A true mil is the angle subtended by an arc of one unit on a radius of 1000 units. Therefore, the circular or military mil is slightly smaller than the true mil, but for all practical purposes they are considered to be identical. An angle would then be expressed in mils as 1,327 mils.

c. **Relation between degrees and mils.—**Degrees may be converted to mils or mils to degrees by using the following simple conversion factor:

$$360^\circ = 6{,}400 \text{ mils}$$

$$1^\circ = \frac{6400}{360} = 17.8 \text{ mils (or 18 mils, approximately)}$$

Hence $10^\circ = 10 \times 17.8 = 178$ mils (or 180, approximately)

$$1 \text{ mil} = \frac{360}{6400} = .056^\circ \text{ (or } 3.4', \text{ approximately)}$$

Hence 100 mils $= 100 \times .056 = 5.6^\circ$ or 5°36′

29. **Base Direction.—**For military purposes direction from one point to another is always expressed in terms of an angle at the initial point between the line joining the points and some fixed or easily established base direction line. There are three base directions from which other directions are commonly measured, namely true north, magnetic north, and grid north, shown on maps by a star, half arrowhead, and y, respectively (Figure 12).

a. **True north.—**The direction to the true north pole. It is used in surveying and other permanent work where great accuracy is required. Where meridian lines or longitude lines are shown on maps they represent true north and south direction. For ordinary military map reading in the field, true north will normally be used only as a base from which declinations are computed. It normally is not used as a direction in marching by compass or orienting a map.

b. **Magnetic north.**—The direction of the north magnetic pole. It is indicated by the N (north seeking) end of all compass needles. It is ordinarily used for field work because it can be found directly by means of the common compass.

c. **Grid north.**—The direction of the vertical grid lines (north-south grid lines) usually found on military maps. On maps with military grid, determination of directions from grid north is convenient because grid lines are located at frequent intervals.

30. **Declination.**—Declination is the difference in direction between true north and either magnetic north or grid north. Hence there are two declinations, magnetic declination and grid declination or gisement.

a. **Magnetic.**—Due to the inequality of distribution of magnetic forces throughout the earth and the fact that these forces are variable with reference to both time and place, there will always be, except in very few localities, an angle between true north and magnetic north. This angle is called the magnetic declination. Where the compass needle points east of true north the magnetic declination is easterly and

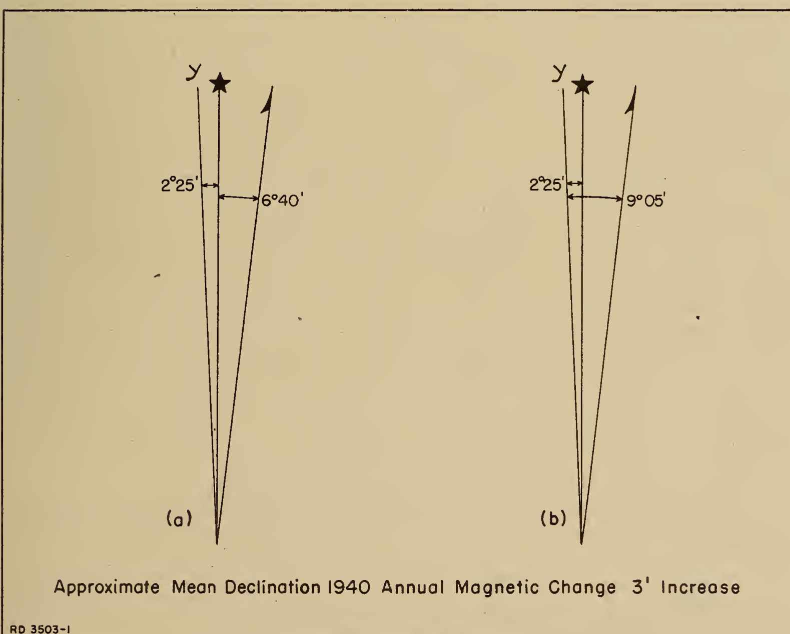


Figure 12.—Declination.

Declination is either shown as in (a) as grid declination (gisement) and magnetic declination measured from true north, or as in (b) as grid declination (gisement), and the total deviation between grid and magnetic.

when the needle points west of true north the magnetic declination is westerly. In order to record and study the magnetic disturbances which cause the compass needle to deviate from true north, maps have been prepared showing points on the surface of the earth where magnetic north coincides with true north. Lines connecting these points are called agonic lines. Points on these maps having the same magnetic declination are located and connected by other lines called isogonic lines. (See Chart Figure 13.)

In the United States, isogonic lines run in a general north and south direction, but meander within wide limits, sometimes doubling back on themselves. The magnetic declination in the United States varies from 25° easterly in the State of Washington to 22° westerly in the State of Maine. It is for this reason that precise maps covering and considerable area are based on the true meridian or a grid system referred to true north.

The discussion up to this point covers magnetic declination as related to place or the location of the observer. There is also the time factor which introduces an additional necessary correction. The location of the magnetic pole and hence the direction of magnetic north changes with the passage of time. This change is computed in annual increments and is called annual magnetic change and is shown with other marginal data on maps of the United States published every 5 years by the U.S. Coast and Geodetic Survey. This annual magnetic change in some localities of the United States may increase or decrease the magnetic declination as much as 4 minutes annually. Every standard map shows in diagramatic form the average relation of magnetic north to true north in the area covered by that particular sheet as of a stated date. The annual magnetic change and how it is applied as a correction to increase or decrease the magnetic declination is also shown as a marginal note. On nautical or coast charts the annual magnetic change is shown as the annual increase or decrease in **variation** and is so noted on the chart near each compass rose, so that the proper corrections may be computed and added, if an increase, or subtracted if a decrease from the magnetic declination indicated on the map as the declination which was correct only for the year indicated.

The method of computing and applying the annual magnetic change is illustrated with reference to figure 12b, as follows:

Magnetic declination in this illustration in 1940, the date of the map, was 9°5′ less 2°25′ equals 6°40′.

Annual magnetic change 3′ increase.

Total magnetic change accumulated to 1944 equals 03′ × 4 years = 12′.

Magnetic declination 1944 would be 6°40′ plus 12′ or 6°52′.

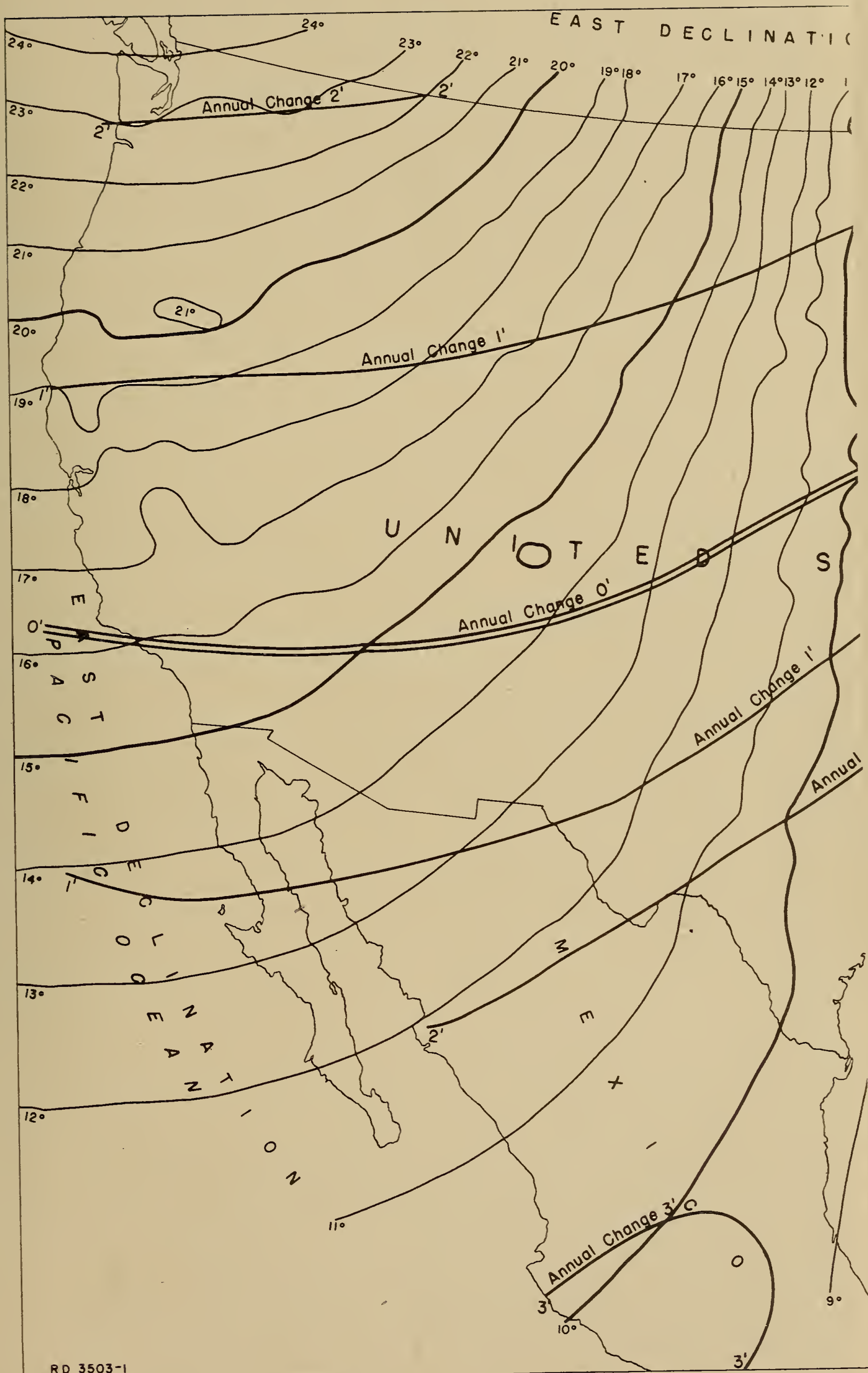


Figure 13.—Lines of equal magnetic declination and

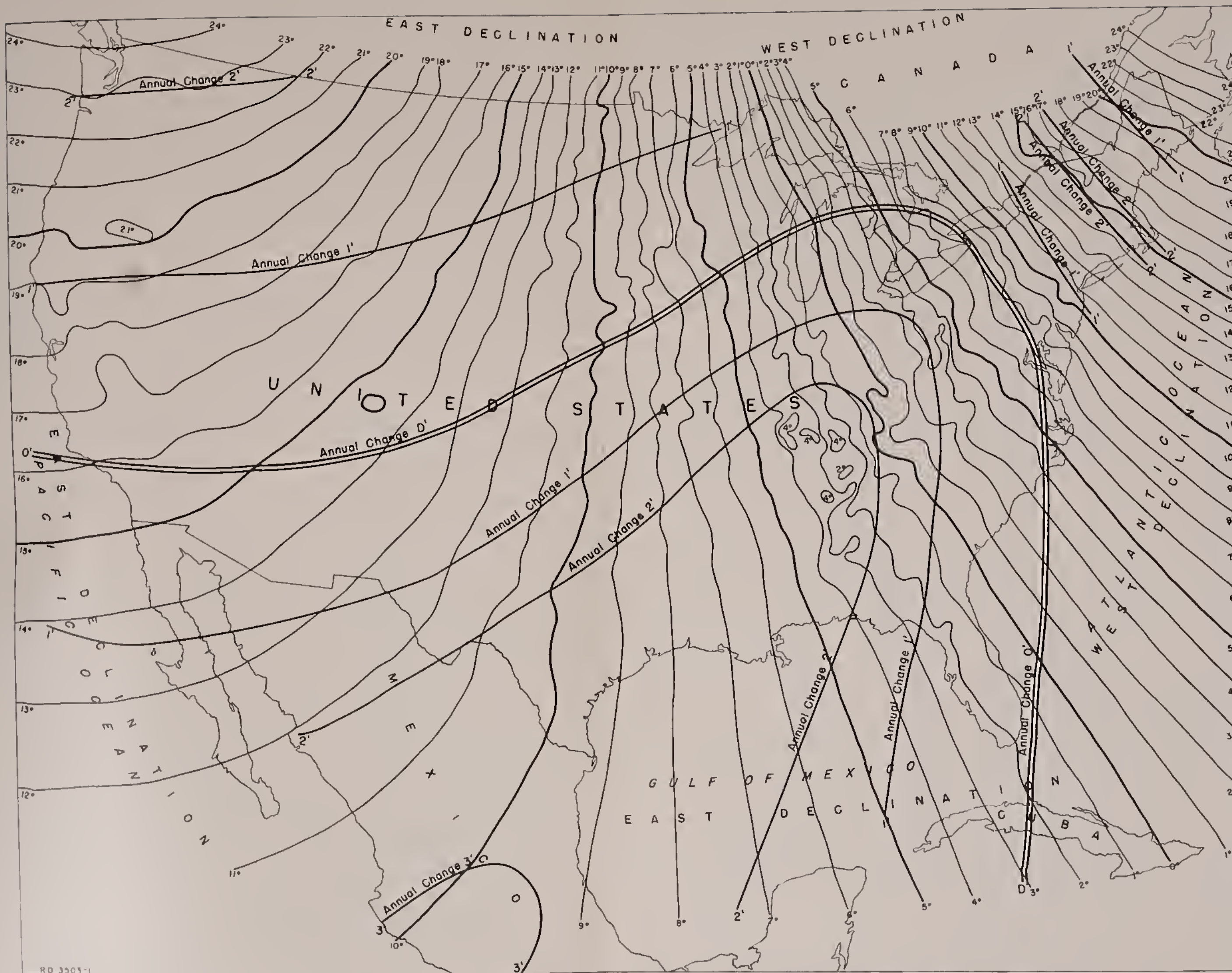
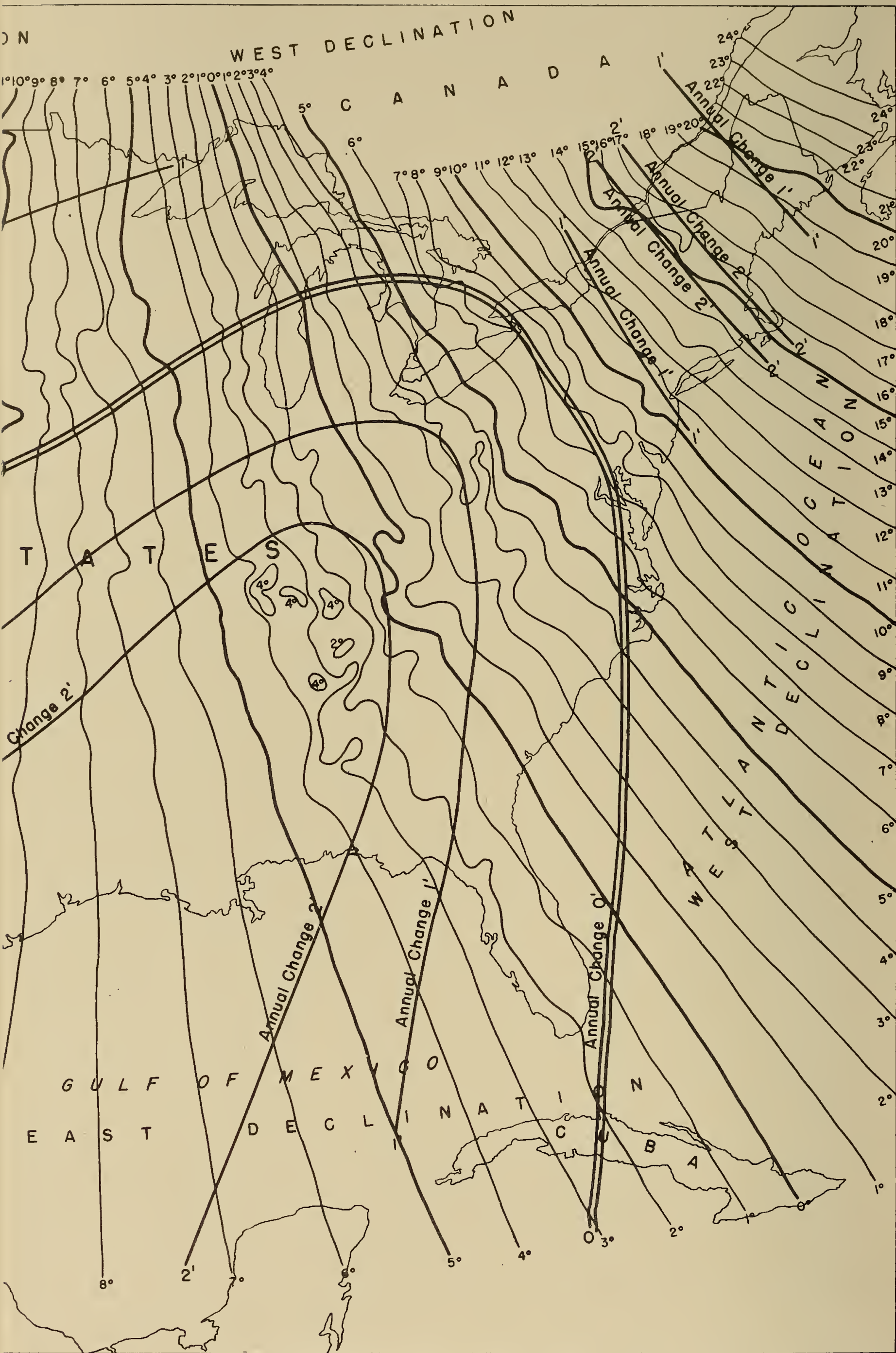


Figure 13.—Lines of equal magnetic declination and of equal annual change in the United States for 1935.



of equal annual change in the United States for 1935.

b. **Grid.**—Grid declination is the fixed difference in direction between true north and grid north. Because of the fact that the meridians converge to meet at the pole while all the north-south grid lines (**Y** lines) of the same grid zone are parallel to one another (see par. 44 for an explanation of the military grid system), there is a deviation betwen true north and grid north except along the central meridian of the grid zone. This deviation is called grid declination or gisement and reaches a maximum of 3° at the edge of the grid zone. It is illustrated in Figure 15 which shows a sketch of the projection of the earth with **abcd** representing the area of a map on which the line **op** is the projection of the central meridian of the grid zone. The north-south grid lines are straight lines parallel to **op.** The projections of all meridians other than **op** are curved converging lines which deviate in direction from the direction of the north-south grid lines. This deviation is designated as west grid declination for all points west of the central meridian, as at point **m,** and as east grid declination for all points east of the central meridian, as at point **s.** The

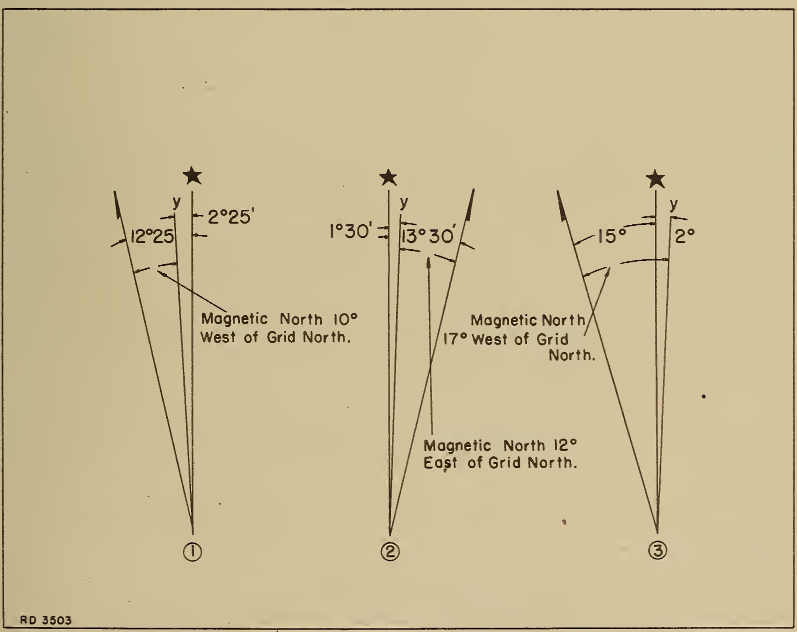


Figure 14.—Determining difference in direction between grid and magnetic north.

declination is determined by finding the angle that the **Y**-grid line makes with true north at the point in question. Although the grid declination varies at different points on a map, this variation on the tactical map is so slight that the average grid declination for the area may be used as the actual grid declination at any point on the map sheet without introducing an appreciable error. Every standard map should show in diagrammatic form the average grid declination for the area represented by the map.

31. **Use.**—Figure 14 illustrates three positions of grid, magnetic, and true north. There are other possible positions. In ordinary map reading the difference in direction between grid north and magnetic north is desired rather than their difference from true north. This can be found in the three example as follows: in Figure 14 ① the difference between magnetic and grid declination is seen by inspection to be 10°0′ (12°25′—2°25′). In ② it is 12°0′ (13°30′—1°30′). In ③ it is 17°0′ (15°0′+2°0′). In the other possible positions of these lines, the declination is determined in a similar manner. When starting to use a map, determine the angle between magnetic north and grid north as described above. Write this down on the map and figure all azimuths on this basis.

32. **Azimuth.**—In describing the position of one point on a map or in the field with reference to some other point, we use a standard system of measuring direction. In military work the azimuth method has been adopted for the purpose. Military azimuths are always measured clockwise from magnetic, true, or grid north. Thus there are three kinds of azimuth for any given line: magnetic, true, and grid.

a. **Magnetic.**—The magnetic azimuth of any given line is the angle measured clockwise from magnetic north to the given line (fig. 16).

b. **True.**—The true azimuth of any given line is the angle measured clockwise from true north to the given line (fig. 16).

c. **Grid.**—The grid azimuth of any given line is the angle measured clockwise from grid north to the given line (fig. 16).

d. **Back Azimuth.**—In reference to Figure 17, assume that with your compass you read the magnetic azimuth **from** CR 47 **to** Hill 172 and found it to be 100°. You then decide that you want to know the azimuth **from** Hill 172 **back to** CR 47. By geometry it is known that angle **a** is equal to angle **a′**; that is, if two parallel lines (the magnetic north lines at CR 47 and Hill 172 are near enough that they can be assumed to be parallel—the convergence is negligible) are cut by a straight line, corresponding angles are equal angles. Also it is known that the sum of all angles on one side of a straight line through a

point are equal to 180°; hence, angle **b** equals 180°. The azimuth **from** Hill 172 **back to** CR 47 is angle **c**, which is the sum of angles **a′** and **b**, or 100° plus 180° equals 280°. This is the magnetic back azimuth of the line **from** CR 47 to Hill 172. Therefore, the back azimuth of a line **from** you **to** a given point is really the azimuth **from** the given point **back to** you. In order to convert forward azimuths to back azimuths:

(1) If the azimuth is less than 180° convert by adding 180°.

(2) If the azimuth is greater than 180° convert by subtracting 180°.

The same rules apply for converting back azimuths to forward azimuths.

Just as a line can have three different forward azimuths—true, grid, and magnetic—there are also three back azimuths for each line. Both forward azimuths and back azimuths should always be stated as true, grid, or magnetic.

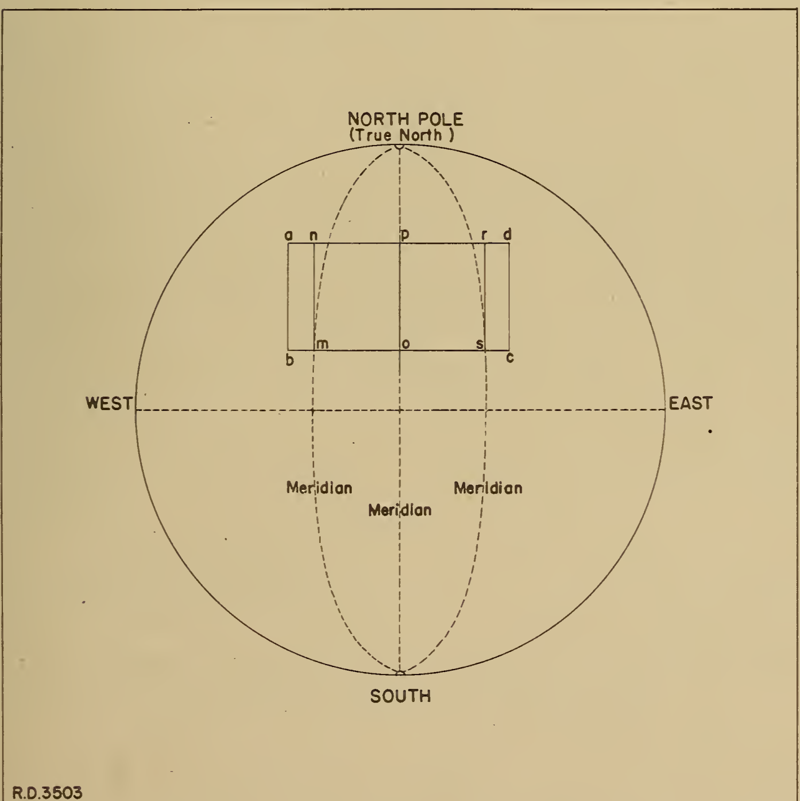


Figure 15.—Diagram illustrating reason for grid declination.

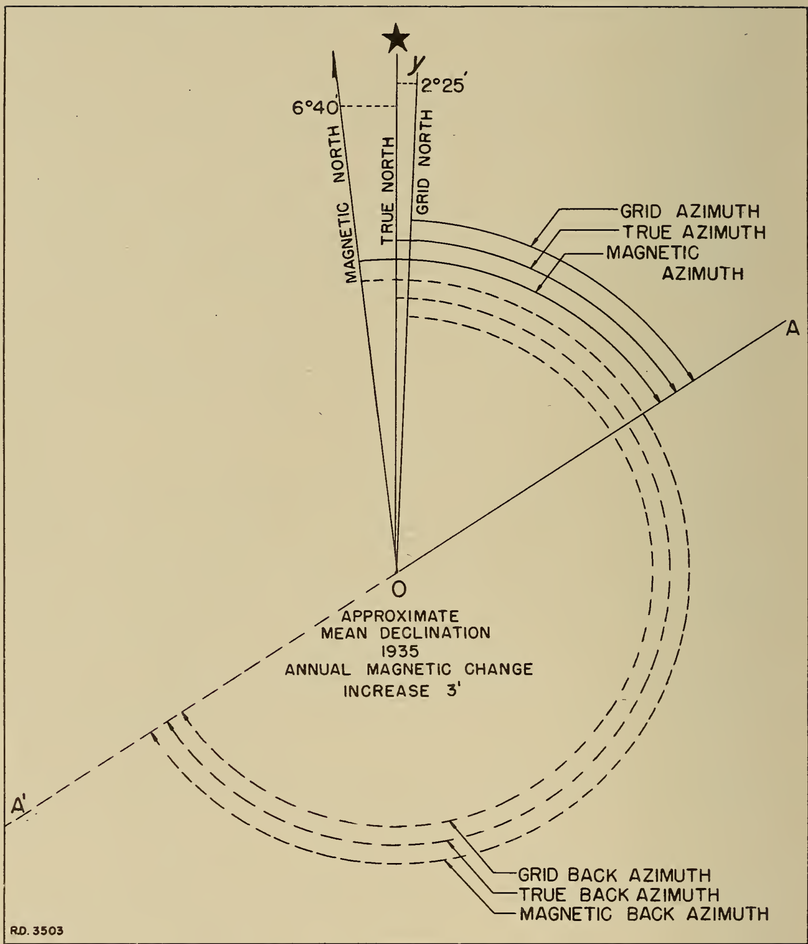


Figure 16.—Example of relationship between three base directions on a map, showing corresponding azimuths and back azimuths of line OA.

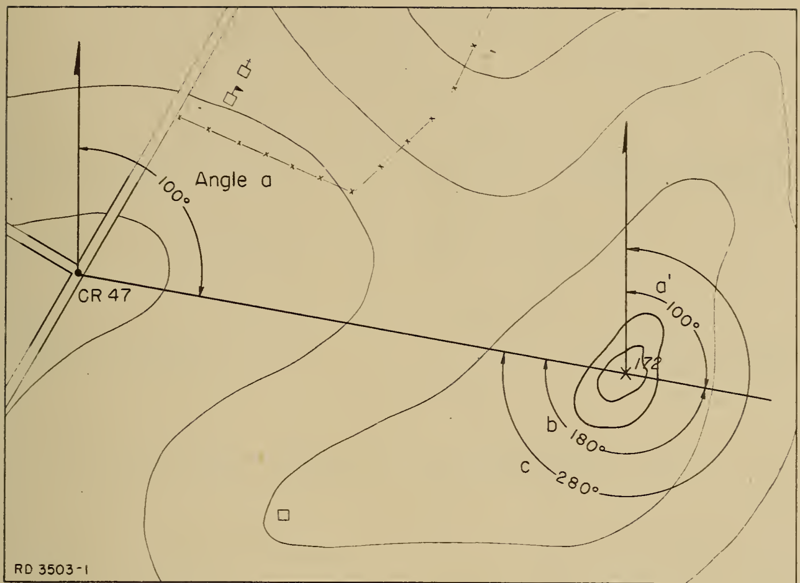


Figure 17.—Back azimuths.

33. **Bearing.**—a. The new lensatic compass gives direction by magnetic azimuths. Watch compasses, many of which are still in use, give directions by bearings. A bearing of a given line is an angle and direction which the line makes with respect to a north or south direction line. Bearings are stated by quadrants (quarters of circles) and never exceed 90°. Figure 18 shows how bearings are measured and indicates relationship between bearings and azimuths. Figure 19 illustrates the expression of a typical direction in each quadrant both as an azimuth and a bearing.

b. The first quadrant reads from North to East, and degrees are identical to the numerals used to express magnetic azimuths in that quadrant.

Example: N 89° E = 89° magnetic azimuth.

c. The second quadrant reads from South to East and bearings are converted to azimuths by subtracting from 180.

Example: S 10° E = 170° magnetic azimuth.

d. The third quadrant reads from South to West and bearings are converted to azimuths by adding 180.

Example: S 29° W = 209° magnetic azimuth.

e. The fourth quadrant reads from North to West and bearings are converted to azimuths by subtracting from 360.

Example: N 15° W = 345° magnetic azimuth.

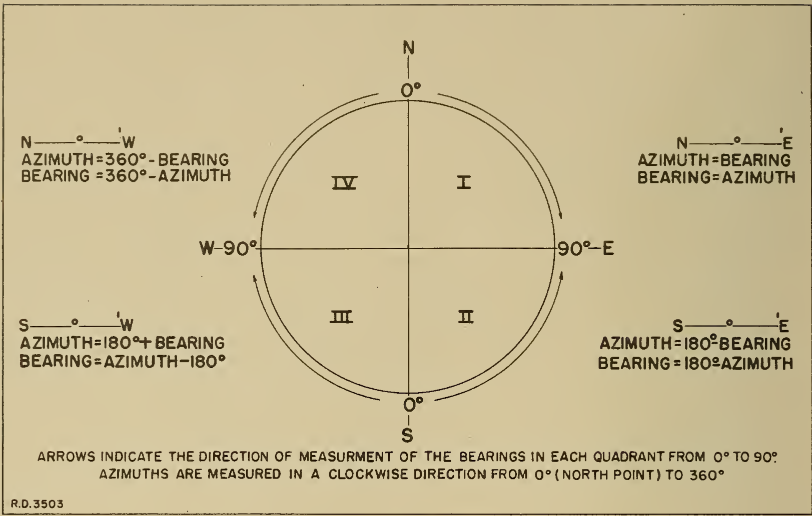


Figure 18.—Diagram indicating relation between bearing and azimuth.

34. Local Magnetic Attraction.—In addition to the compass variation caused by magnetic declination, the magnetic compass is affected by the presence of iron and electrical fields of magnetism. Consequently, great care should be taken not to approach such local magnetic attraction within a distance which will cause the magnetized compass needle to deviate while making observations to determine direction. The rifle, pistol, and helmet must be laid aside when reading the compass. The following are the minimum safe distances for visible masses of iron and electrical fields of magnetism:

	Yards
High tension power lines	150
Heavy gun	60
Field gun and telegraph wires	40
Barbed wire	10

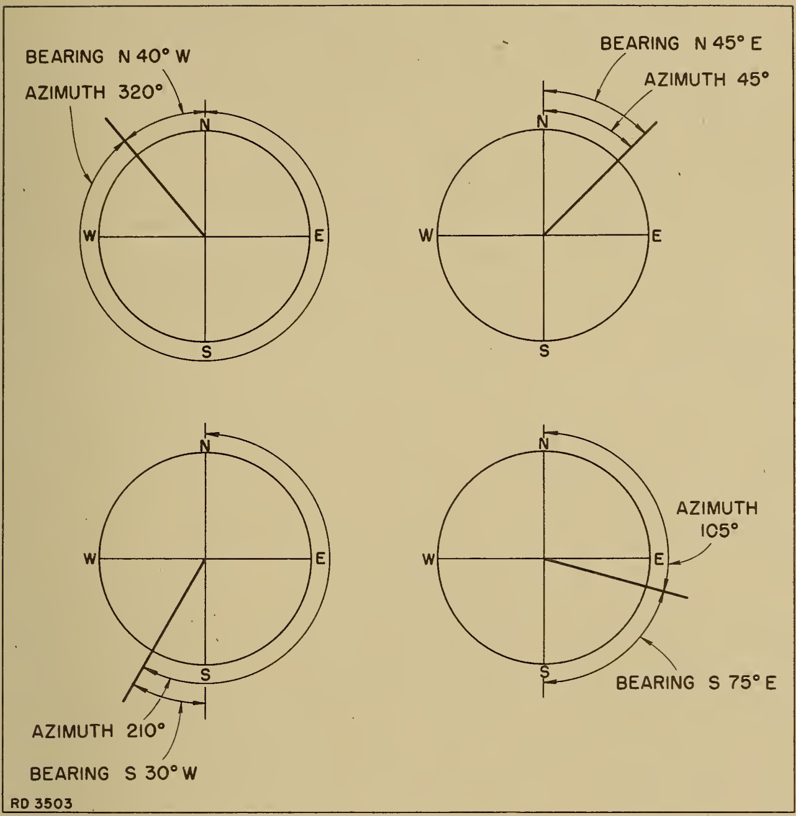


Figure 19.—Typical direction expressed as azimuth and as bearing.

35. Determination of Direction by Field Expedients.—a. **By aid of watch and sun.—**North can be determined with an error of less than 8° if the sun is visible and a watch showing approximately the correct sun time is available. Point the hour hand, watch held face up, at the sun. This is facilitated by casting the shadow of a vertical pencil across the face of the watch and by then bringing the hour hand into this shadow. A line drawn from the center of the dial to a point halfway on the smaller arc between the hour hand and the 12 of the watch will point south. In the Southern Hemisphere the watch must be held face down and this line will point north. This method is difficult to use when the sun is very high in the heavens and is of little or no use in the Tropics.

b. **By rising and setting of celestial body.**—Observe the magnetic azimuth of the sun, a planet, or a bright star at rising and setting on the same day or at setting on one day and rising the next. Add these two azimuths together. Take the difference between this sum and 360°. One-half of this difference is the declination of your compass—east, if the sum of the azimuths is less than 360°; west, if it is greater. In using this method the observations are best taken when the object is just above the true horizon, or at a gradient of zero. This can usually be done if a high point is chosen for observation. If this cannot be done, be careful to take both observations with the object at the same gradient, as determined with a clinometer. This is most important with the sun. Under the least favorable conditions an inequality of 1° in the gradients at the time of observation on the sun may introduce an error of ½° in the result. In using a star, choose one which rises nearly east from the point of observation. If this is done the inequality of a degree in the gradients will be immaterial. Both observations need not be made at the same point, but should not be more than 10 miles apart in east and west or north and south directions.

c. **By aid of sun and plumb line.**—On a level piece of ground, lean a pole toward the north and rest it in a crotch made by two sticks. Suspend a weight from the end of the pole so that it nearly touches the ground; then, about an hour before noon, attach a string to a peg driven directly under the weight and, with a sharpened stick attached to the other end of the string, describe an arc with a radius equal to the distance from the peg to the shadow of the tip of the pole. Drive a peg on the arc where the shadow of the tip of the pole rested. About an hour after noon, watch the shadow of the tip as it approaches the eastern side of the arc and drive another peg where it crosses. By means of a tape or string, find the middle point of the straight line joining the last two pegs mentioned. A straight line joining this middle point and the peg under the weight will, for all practical purposes, be true north.

d. **By means of North Star (Polaris).**—Ursa Major (Big Dipper) is the easiest constellation to distinguish and provides the best means for locating the North Star. The two "pointers," or the stars forming the lip of the dipper, point to the North Star (Polaris) at all times as the Dipper appears to circle the pole. On the opposite side of Polaris and at about the same distance from it is the constellation of Cassiopeia. Its form is that of the letter "W." The great importance which attaches to the North Star is that it revolves about the celestial North Pole in a small circle whose radius is slightly more than 1°. It therefore appears to the

eye to be always in the same place. An observation of the North Star to determine true north, when the Dipper and Cassiopeia are above and below the North Star, will give the declination of the compass to within the least reading of the compass.

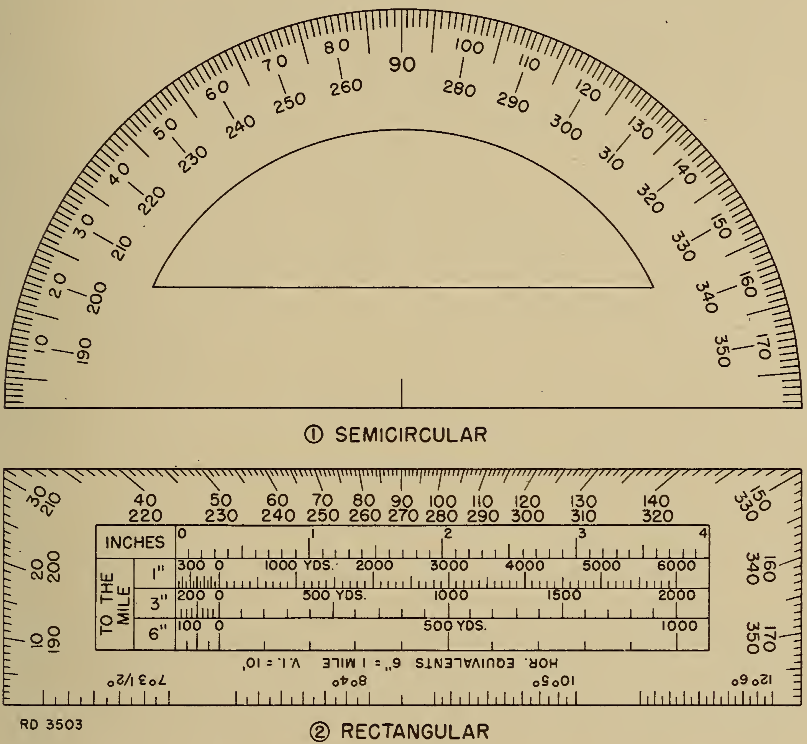


Figure 20.—Military protractors.

36. **Protractor.**—Angles of azimuth or bearing are measured or laid off on a map by means of an instrument called a protractor. Figure 20 illustrates two types; the semicircular type is the more common. Each represents one half of an azimuth circle. In the figure it will be noted that two scales are shown, one reading from 0° to 180° and one from 180° to 360°, used for reading azimuths greater than 180°.

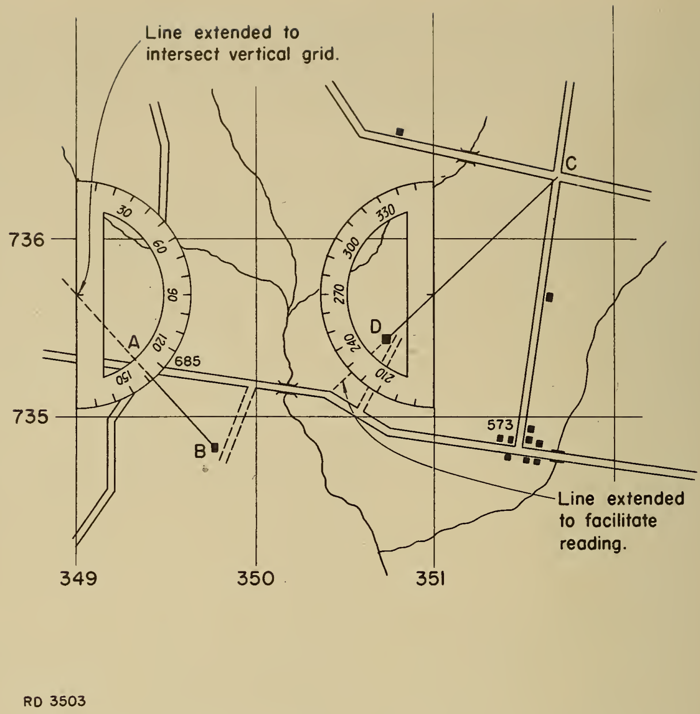


Figure 21.—Using protractor to measure map azimuth.

37. Use of Protractor.—a. To measure azimuth of any line on map (Figure 21.).—(1) Required, to find the grid azimuth of the line from the CR (crossroads) at A to the house at B. Extend the line AB until it intersects the 349 grid line. Lay a protractor on the map with its center at this intersection and the straight portion lying along the 349 grid line. Read the grid azimuth of AB. This azimuth is seen to be 137°.

(2) Required, to find the grid azimuth of the line from the CR at C to house at D. Extend the line CD a sufficient distance so that it will extend beyond the edge of the protractor. Lay the protractor on the map with its center at the intersection of CD with the 351 grid line and the straight portion lying along the 351 grid line. Since the azimuth of the line is greater than 180°, the scale reading from 180° to 360° will be used to determine the azimuth of CD. This azimuth is 226°.

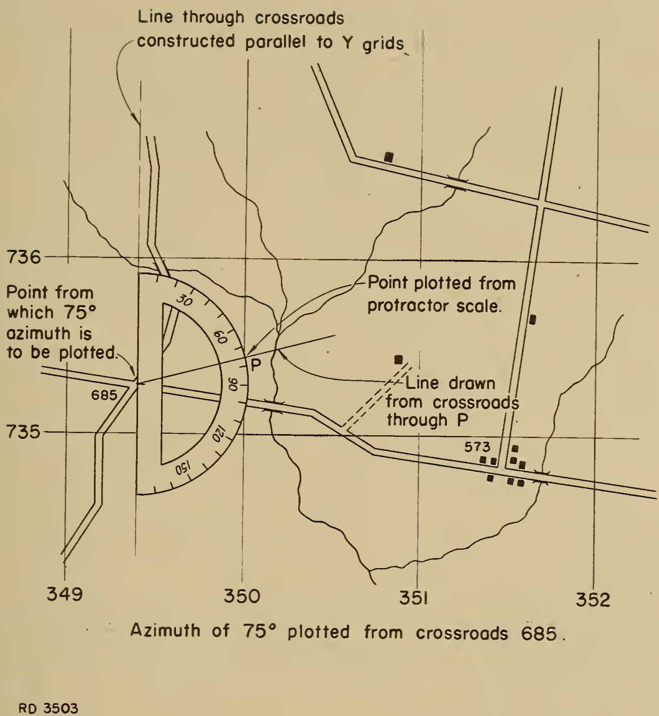
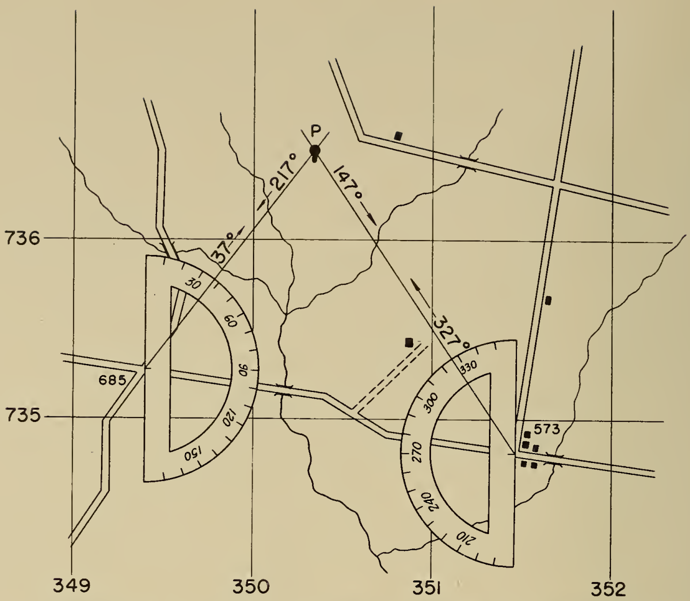


Figure 22.—Plotting azimuths.

b. **To plot on map line with given azimuth** (fig. 22.).—Required, to plot from CR (crossroads) 685 a line with a grid azimuth of 75°. Construct a line through the CR parallel to the north-south grid. Lay a protractor on the map with its base on the line and its center at the CR. Plot the point P at the 75° reading on the outer scale of the protractor. Remove the protractor and draw a line from the CR through P.

38. Locating Point by Intersection and Resection.—a. **General.**—Sometimes it will be necessary for patrol leaders or other military personnel to determine map position of points or objects located either in enemy or other inaccessible territory. Also it may be necessary to find their own map position from inaccessible but visible points that are shown on the map. Figure 23 shows how both these operations can be accomplished.



Where azimuths from road junctions to gun are known, their plotting gives location of the gun. Where azimuths from gun to road junctions are known, they can be converted to back azimuth and gun position plotted as before.

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Figure 23.—Location by intersection and resection.

b. **Intersection.**—Required, to find map position of an enemy gun that has been spotted at the point P (Figure 23) on the ground. Both CR 685 and RJ 573 are in our territory and the enemy gun is visible from both of these points. By means of a prismatic compass, the magnetic azimuth was taken from CR 685 to the gun at P. Converted to grid azimuth, it was 37°. This grid azimuth was then plotted from CR 685 as shown. Likewise, the magnetic azimuth from RJ 573 to P was taken and converted to grid azimuth. The grid azimuth was 327°. This azimuth was then plotted from RJ 573. The intersection of these plotted azimuths gives the map position of the gun at P which can be checked by additional similar observations. Observation points should be selected such that the plotted azimuths cross at as near a 90° angle as possible so that the point of intersection is definite.

c. **Resection** (Figure 23).—(1) Required, by someone at P, to find map positions of gun at P. This gun is in our territory but no landmarks or other easily identified terrain features are close enough to permit location from these points. However, CR 685 and RJ 573 are visible from P and are also shown on the map. The azimuths from P are read to both

road intersections. These azimuths are then converted to grid **back** azimuths and plotted as before, giving the map position of the gun.

(2) Note that in using these two systems no measurement of distance is required. Location of position is determined merely by reading two angles and plotting two lines.

SECTION 6

COORDINATES

39. **General.**—In military operations it is frequently necessary to refer to points on the ground or terrain features in short, convenient, unmistakable terms. The easiest way to accomplish this is to designate the point when given on a map by its name or number. Military maps often show names or numbers of all important locally known features. Hills, road junctions, and crossroads are often given numbers usually in terms of their elevation in feet above sea level, thus serving the dual purpose of designating the feature and also giving its elevation. But it is not possible to number or name all features of military value on a map. Also it is often difficult to find such points on the map even when they are named or numbered. Thus some simple method or system for describing the position of a point or a place on a map is essential for quick and accurate identification. The use of coordinates has been adopted to serve this purpose.

Systems of Coordinates.—a. In order to express absolute or relative positions of points, either on a map or on the terrain, one or more of the several different systems of coordinates may be selected. Each system has its appropriate uses. The names of the systems in most common use are:

(1) Polar coordinates.

(2) Rectangular coordinates.

(3) Geographic coordinates.

(4) Grid coordinates.

(5) Thrust line coordinates.

b. Rectangular and polar coordinates are classified as relative coordinates because they are determined by reference to a base point (and direction) local to some map and selected by some individual. Since an indefinite number of persons may be using a map of the same area, but perhaps using different base points, a given point on the map could therefore have an indefinite number of polar or rectangular coordinates assigned to it.

Geographic and grid coordinates are termed absolute coordinates because each is determined by reference to a permanently fixed base point and direction which have been officially adopted for that purpose. Thus only one set of geographic coordinates or, for any grid zone, only one set of grid coordinates can be assigned any point and this set of coordinates is not affected by the selection of map.

Thrust line coordinates are neither absolute nor relative but combine some of the features of both types, because they are measured from a temporarily fixed base point and a temporarily established base direction so that for only a limited period of time are the coordinates absolute.

40. Polar Coordinates.—Polar coordinates are used in designating points located with a compass in the field and in designating positions on maps not equipped with the military grid. They consist of an angle from a known base direction and a distance from a known base position. The base position is the origin of coordinates. It may be a fixed landmark, a survey monument, or any other position easily identified on the map and on the ground. The base direction may be true, magnetic, or grid north or south. The angle may be expressed as azimuth or bearing, the distance in any convenient distance unit. The base position or origin should be fully described.

Example: Battle map, Fort Belvoir, 1:20,000 (1935), BM 38, Accotink (village), distance 500 yards N.30°W. magnetic.

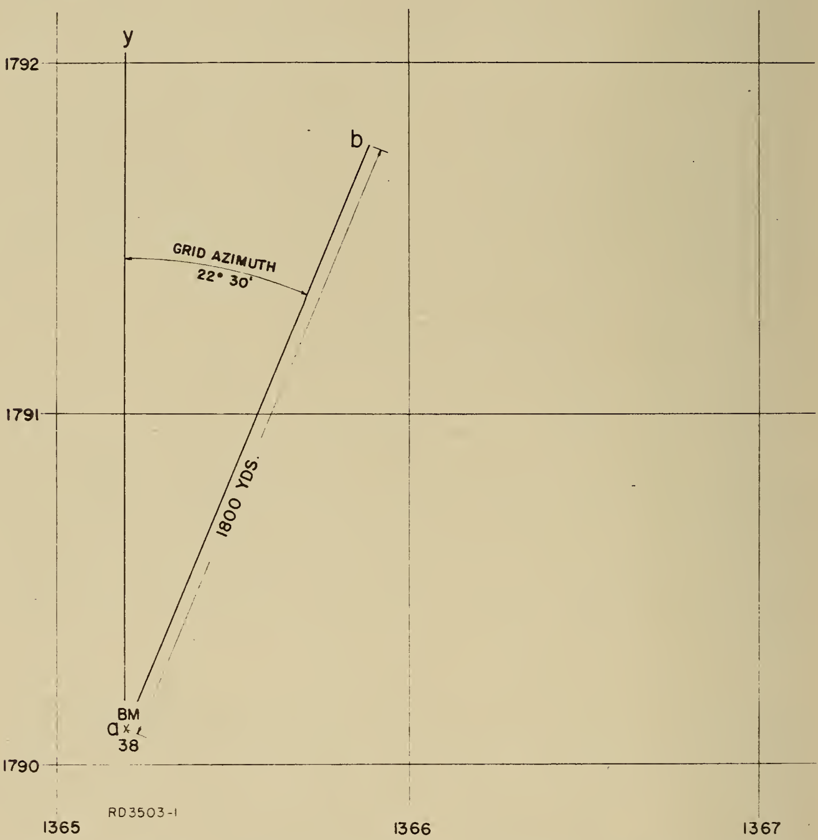


Figure 24.—Polar coordinates: BM 38. Accotink (village), distance 1,800 yards on grid azimuth 22°30′.

NOTE: Figures 24 and 25 refer to the Fort Belvoir map because it is issued with this text. Polar and Rectangular coordinates are used chiefly on ungridded maps, but may be plotted on gridded maps.

Battle map, Fort Belvoir, 1:20,000 (1935), BM 38, Accotink (village), distance 1,800 yards, on grid azimuth 22°30′. The point so designated is marked **b** in figure 24. The base position, BM 38, is marked **a**, the distance from the base position is the line **ab**, the base direction (grid north) is **ay**, and the angle from the base direction is **yab**.

In dealing locally with many points common to a single map sheet, the sheet reference may be omitted.

a. **To plot position of point, polar coordinates of which are given.**—(1) Locate on the map the landmark or other base position (origin) given.

(2) Through the base position draw a guide line parallel to the base direction.

(3) With a protractor, point off from the guide line radially about the base position the given angle (azimuth or bearing).

(4) Through the point thus established and the base position (origin) draw a guide line.

(5) Along this guide line from the base position lay off the given distance to scale.

b. **To determine polar coordinates of map position with respect to given position and given direction.**—(1) Locate on the map the given base position and through it draw a guide line parallel to the base direction.

(2) Draw another guide line through the base position and the point whose polar coordinates are sought.

(3) With the protractor, measure the angle (azimuth or bearing) which the direction line established in (2) above makes with the base direction line established in (1) above.

(4) With a suitable scale at the RF of the map, measure the distance from the base position to the point the coordinates of which are sought.

41. Rectangular Coordinates.—Rectangular coordinates are used in designating points on ungridded maps without the aid of a protractor. They consist of two distances measured at right angles from a base position. The base position (origin) should be a landmark, survey monument, or other well-established position. The base position, distances, and directions should be fully stated, thus:

Battle map, Fort Belvoir, 1:20,000 (1935), BM 38, Accotink (village), 1,500 yards east (magnetic), 1,100 yards north (magnetic). The point so designated is marked **c** in Figure 25. The base position, BM 38, is marked **a**, the base direction (magnetic north) is **am**, the direction of the line **ab** (grid east) makes a right angle with the line **am**, and the respective distances are **ab** and **ac**.

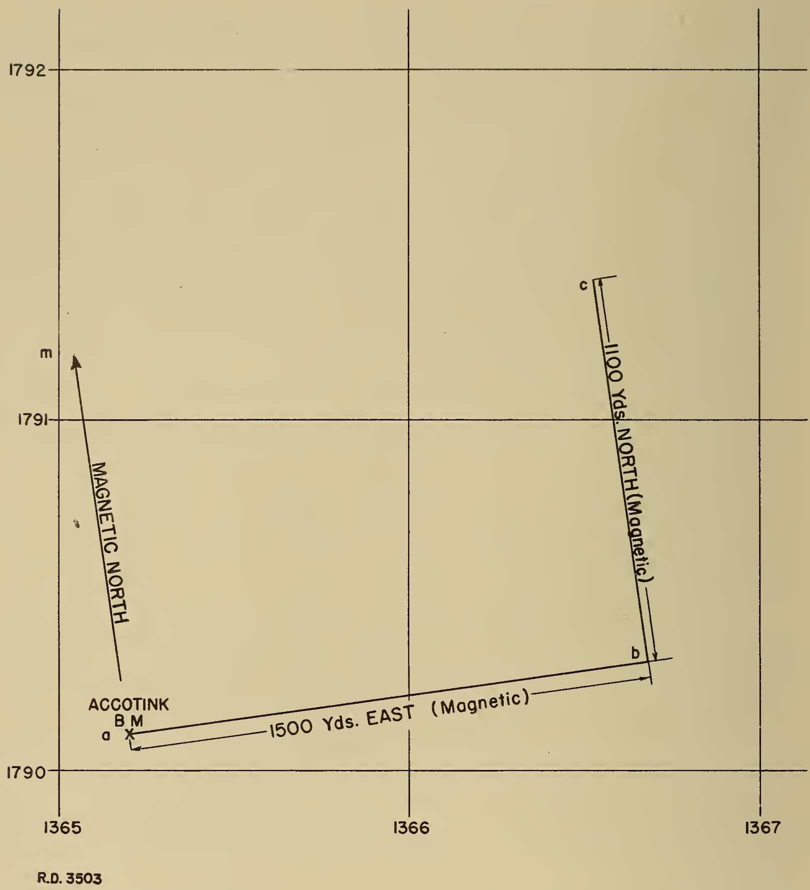


Figure 25.—Rectangular coordinates: BM 38, Accotink (village), 1,500 yards east magnetic, 1,100 yards north magnetic.

a. **To plot map position, rectangular coordinates of which are given.**—(1) Locate on the map the base position (origin) given.

(2) Through the base position draw a guide line parallel to the base direction.

(3) Through the base position draw a guide line at right angles to the base direction.

(4) From the base position along these lines point off to scale the respective distances in the respective directions as given.

(5) Treat these distances as the adjacent sides of a rectangle; complete the rectangle (other two sides) with construction lines. The intersection of these two construction lines is the point sought.

b. **To determine rectangular coordinates of map position with respect to given base position and direction.**—(1) Identify on the map the given point and the given base position.

(2) Through the base position draw a guide line parallel to the base direction.

(3) Through the base position draw a guide line at right angles to the base direction.

(4) Through the given point drop perpendiculars to the lines established in (2) and (3) above.

(5) From the base position scale the distance along the guide lines of (2) and (3) above to the respective perpendiculars. These distances are the rectangular coordinates sought.

42. **Scale of Proportional Parts.**—Map reading sometimes requires the measuring or location of a point or line between parallel lines. If the lines are spaced an equal distance, this presents no problem, but if they are unequally spaced as in the case of geographic grid lines a special method of measurement is required. This may be done with any graduated ruler because of certain properties of parallel lines.

a. In Figure 26, lines AB and CD are parallel and spaced an unequal distance apart. We wish to find the percentage of the total distance point X is from line AB.

b. Select any scale on an engineer's scale that is readily converted to 100. (An engineer's scale is divided decimally.) In this case 20 scale was selected; 5 units is a convenient length and easily converted to 100 by multiplying by 20.

c. Place the scale so the 0 is on line AB and the 5 is on line CD.

d. With the 0 on line AB and the 5 on line CD, slide the scale along the parallels until the point X lines along the scale.

e. The reading of 1.9 is converted to percentage by multiplying by 20; hence, $1.9 \times 20 = 38\%$ of the total distance away from AB to CD.

f. If the lines AB and CD were a thousand yards apart, point X would then be 380 yards from AB.

NOTE: The angle the scale is held to the lines is immaterial as long as the 0 is held on the base line (in this case AB) and the other selected number (in this case 5) is held on the other line.

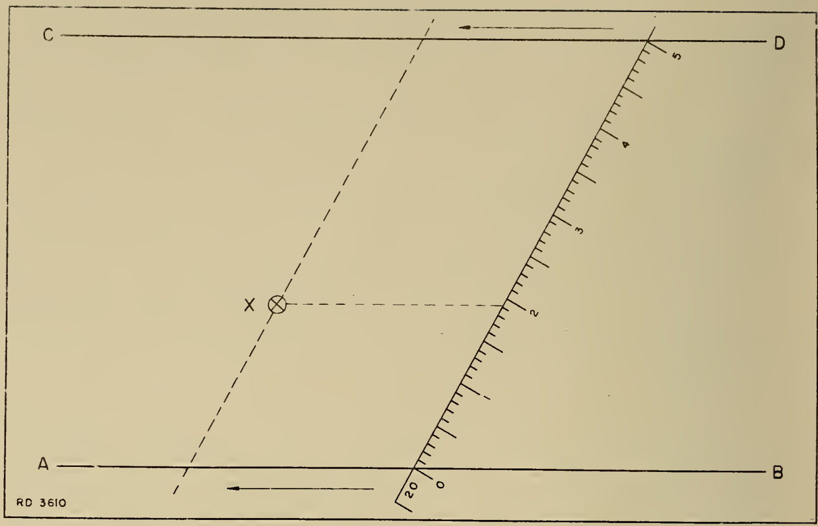


Figure 26.—Measuring between parallels.

g. If the lines AB and CD were part of a geographic grid and were one minute apart and you wished to find the number of seconds point X was from line AB, the method would be modified as follows:

60 seconds = 1 minute

$5 \times 12 = 60$ (As before 5 units is a convenient length and in this case easily converted to the total of 60 parts by multiplying by 12.)

$1.9 \times 12 = 22.8 = 23''$

Therefore, point X is 23″ from AB.

43. **Geographic Coördinates.**—The system of latitude and longitude lines projected on a map represents the geographic or spherical grid covering the earth. In this system the base position (or origin) is the intersection of the meridian of Greenwich, known as the prime meridian, with the Equator. The base direction is true north (or south). Distance on the spheroid (earth) is reckoned in units of degrees, minutes, and seconds of latitude up to 90° north or south of the Equator, and in degrees, minutes, and seconds of longitude up to 180°, east or west of the prime meridian. The location of any point on the surface of the earth is defined in terms of the parallel of latitude and the meridian of longitude which intersect at the point, thus, latitude 38°32′20″ N., longitude 77°34′30″ W. The latitude and longitude of a point constitute its geographical or spherical coordinates. However, meridians

of longitude converge at the poles. Therefore, units of longitude decrease in units of linear distance from a maximum at the Equator to zero at the poles. Since the sphere cannot be developed as a plane, other variations are introduced in maps by the characteristics of projections used in map construction. While units of latitude and longitude can be converted to distances in meters, yards, miles, etc., by computation or use of tables, the spherical units would not occur, except by fortunate coincidence, in rational multiples of the linear unit. Lines of the spherical grid are necessarily curves or projections of curved lines and vary with latitude and projection. Such variations from straight lines and true distances within the scope of a sheet of the terrain or the tactical map are negligible. For practical map-reading purposes they may be disregarded and the spherical grid may be treated graphically in all respects as a rectangular grid. The 5-minute lines of the geographic grid appear in full or by border registration on topographic sheets. The 1-minute lines of the geographic grid appear registered on some large-scale maps by border ticks and grid intersections. Geographic coordinates are used in designating positions in large indefinite areas, in unmapped areas, and on geographic (ungridded) maps.

On some sheets (for example, the Ft. Belvoir and Vicinity, 1:20,000) the overlap of the adjacent military grid zone is also shown by a series of border ticks and grid intersections. On maps of this type, great care must be taken in distinguishing between the two grids.

a. **To plot positions of point, geographical coordinates of which are given.**—(1) Identify on the map the two lines of the geographic grid, both of latitude and longitude, which fall nearest to and on each side of the position to be plotted. This may be readily done by inspection of the map in comparison with the given coordinates. In case the lines of the grid do not appear in full on the map, draw in the lines by joining the border ticks and grid intersections. In either case the point sought falls somewhere within the quadrangle whose sides are lines (arcs) of known latitude and longitude. For a battle map (1:20,000), this is a 1-minute quadrangle (60 seconds by 60 seconds). For a topographic sheet, this is a 5-minute quadrangle (300 seconds by 300 seconds).

(2) The problem then reduces itself to the mechanical operation of dividing the quadrangle into seconds of longitude and seconds of latitude, pointing off the seconds place required by each coordinate. One of these points will fall on the meridian of longitude which passes through the point sought. The other will fall on the parallel of latitude which passes through the point sought. The significant parallel of latitude and meridian of longitude are now struck in as guide lines. Their intersection is the point sought.

(3) Points on the significant parallel of latitude and meridian of longitude are readily located with the engineer's scale used as a diagonal scale of proportional parts between the available grid lines. For the 1-minute grid the scale should be placed across the lines at any angle so that 60 convenient divisions span the distance. For the 5-minute grid 300 divisions of the scale should span the distance between lines. In each case each division of the scale indicates a second of latitude or longitude, depending upon which coordinate is being plotted.

(4) Figure 27 illustrates the location of a point **a,** the geographic coordinates of which are latitude 38°42′20″ N., longitude 77°13′30″ W.

b. **To determine geographic coordinates of map positions.**—(1) By inspection of the map, identify the grid quadrangle in which the point lies, drawing in the sides of the quadrangle when the grid appears registered only. The value in degrees and minutes of the meridians of longitude and parallels of latitude which form this quadrangle appears in print on the borders of the map. The problem, then, is to determine the position of the point within the quadrangle in seconds of latitude and seconds of longitude.

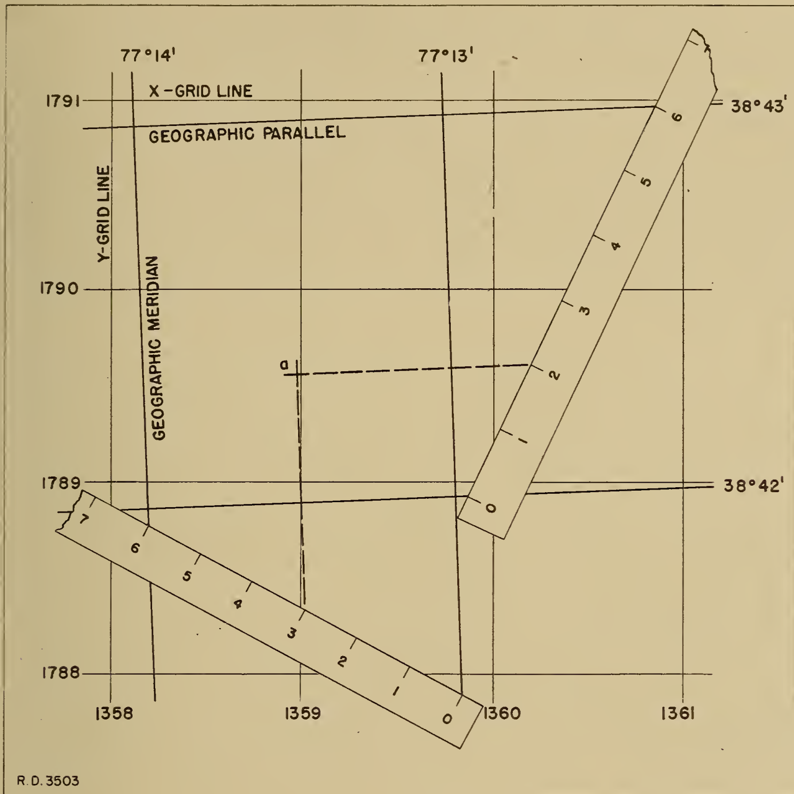


Figure 27.—Geographic coordinates: latitude 38°42′20″N., longitude 77°13′30″W.

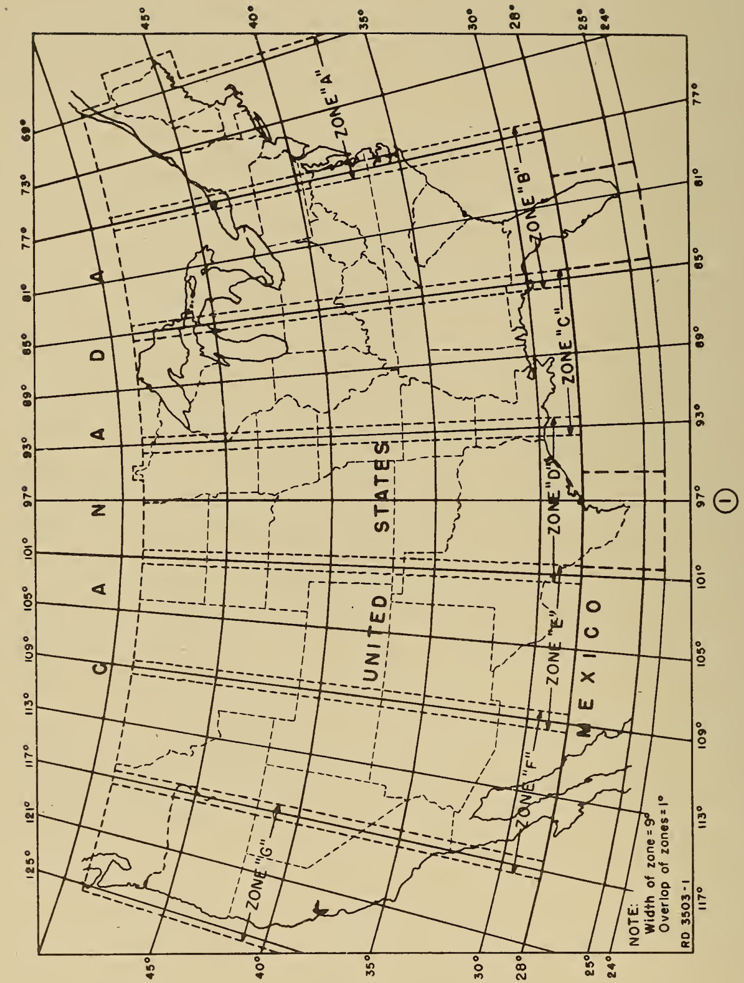
(2) Use the engineer's scale as a scale of proportional parts as described in Paragraph 43a(3) to establish the seconds lines within the significant quadrangle, except in each case (the two positions of the scale, one for latitude and one for longitude, respectively) the scale should pass through the point whose coordinates are desired. The number of seconds sought may now be read directly from the edge of the scale at the point in the direction of increasing grid values within the grid quadrangle. This added to the recorded value in degrees and minutes of the side of the significant quadrangle lowest in value yields the coordinate sought in degrees, minutes, and seconds.

44. Military Grid System.—a. The standardized system of rectangular coordinates discussed in paragraph 46 is the grid system devised for use on military maps in order to avoid the difficulties and inconveniences inherent to the spherical

grid. A rectangular grid superimposed on a polyconic projection of the whole continental United States would prove no more useful than a map on that projection and for the same reasons. Distances on the rectangular grid would vary prohibitively from true ground distances in the distorted areas near the edges of the map. However, by limiting the width of the projection to about 9° of longitude, the maximum distortion along the edge of the projection never exceeds 2.57 yards per 1,000 yards, or about 1/4 of 1 percent, an error of no military consequence, since the changes in dimensions of an ordinary map sheet due to weather conditions may exceed that amount.

b. For the purposes of superimposing the rectangular grid, the northern half of the continental Western Hemisphere has been divided into seven zones, each 9° of longitude wide. Each zone is a separate polyconic projection. When the military grid system was first established it extended from 28° N. latitude to 49° N. latitude. This system, known as the continental system, was sufficient for continental United States only. Later, in order to take care of Panama and the Caribbean area, the equatorial system, extending from 7° N. to 28° N., was set up. These two systems have different Y origins, and hence any point in this area will have the same X-Coordinate in both systems but different Y-coordinates. All grids are identical in structure but each has a separate origin 8° of longitude distant from its neighbor. The grids therefore overlap 1° of longitude along the borders, with a net width of 8° of longitude between the central meridians of the overlaps. These zones are designated by a letter in accordance with the following table, that portion of the State of Maine falling to the east of longitude 68°30′ being included in zone A.

c. The limits of the grid zones are shown in table I. The zone letter appears on all maps containing grids. In designating points by grid coordinates, the name of the map sheet and not the zone letter should be used as primary reference.


CANADA
UNITED STATES
MEXICO
ZONE "A"
ZONE "B"
ZONE "C"
ZONE "D"
ZONE "E"
ZONE "F"
ZONE "G"
NOTE:
Width of zone = 9°
Overlap of zones = 1°
RD 3503-1
1

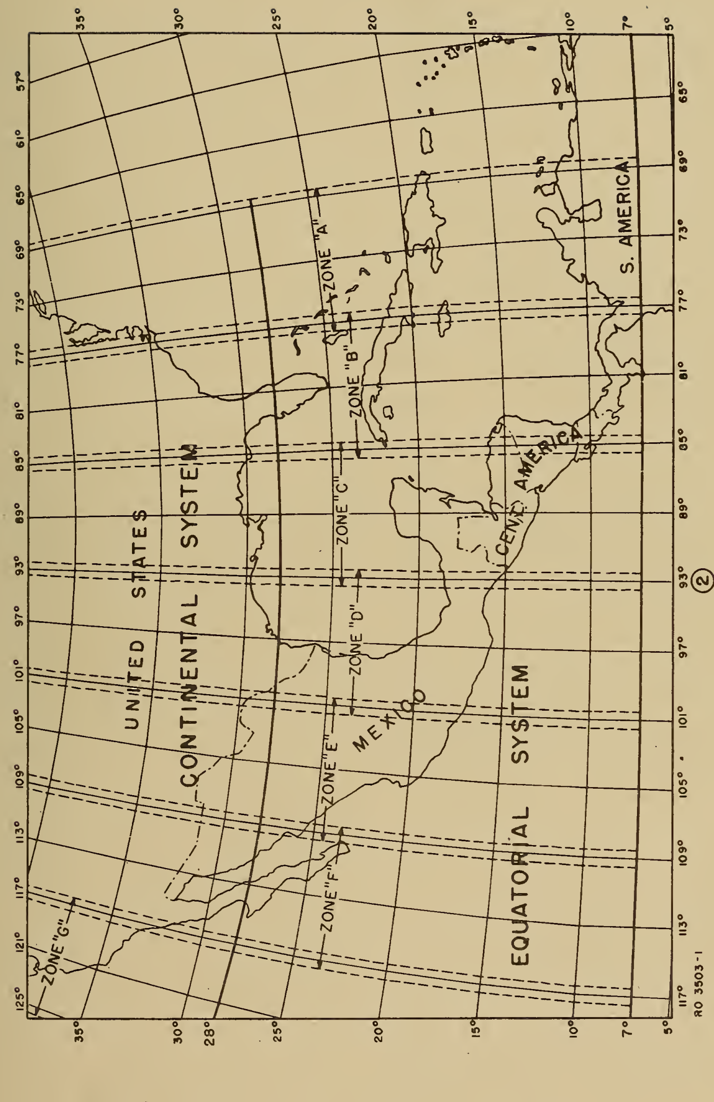

UNITED STATES
CONTINENTAL SYSTEM
MEXICO
CENT. AMERICA
S. AMERICA
EQUATORIAL SYSTEM
ZONE "A"
ZONE "B"
ZONE "C"
ZONE "D"
ZONE "E"
ZONE "F"
ZONE "G"
RO 3503-1
2

TABLE I

Grid zone systems in northern half of continental Western Hemisphere.

Zone	Limiting meridian of zones	Origin of co-ordinates X	Grid values assigned to origin X yards	Equatorial system		Continental system	
				Origin of coordinates Y	Grid values assigned to origin Y yards	Origin of co-ordinates Y	Grid values assigned to origin Y yards
A	68°30′ W., 77°30′ W	73° W	1,000,000	Equator	Zero	40°30′ N	2,000,000
B	76°30′ W., 85°30′ W	81° W	1,000,000	do	do	40°30′ N	2,000,000
C	84°30′ W., 93°30′ W	89° W	1,000,000	do	do	40°30′ N	2,000,000
D	92°30′ W., 101°30′ W	97° W	1,000,000	do	do	40°30′ N	2,000,000
E	100°30′ W., 109°30′ W	105° W	1,000,000	do	do	40°30′ N	2,000,000
F	108°30′ W., 117°30′ W	113° W	1,000,000	do	do	40°30′ N	2,000,000
G	116°30′ W., 125°30′ W	121° W	1,000,000	do	do	40°30′ N	2,000,000

45. **Continental System.**—a. In each zone the intersection of its central meridian with the parallel of latitude 40°30′ is selected as the origin of coordinates designated by O. The central meridian is chosen as the Y-axis and a right line tangent to latitude 40°30′ at O is chosen as the X-axis. In terms of yards, the grid coordinates of all 5-minute intersections of latitude and longitude within the whole grid zone are computed with respect to these axes and the origin O. The coordinates of intersections in all other quadrants, except the first, involve some negative quantities which are undesirable for simplicity. In order to make positive all coordinates which appear on military maps embraced within the zone, the computed values are transferred to a new origin O′ exactly 1,000,000 yards grid west and 2,000,000 yards grid south of the origin O. This is effected by simply adding 1,000,000 yards to all computed X-coordinates and 2,000,000 yards to all computed Y-coordinates. It is the point O′ and axes O′-X and O′-Y to which all grids and grid values appearing on all military maps are related. The original origin O has no further significance. This scheme is shown in Table I, and the rectangular grid system illustrated therein is referred to as the military grid system.

b. Since the grids for all zones are identical in structure, only one set of original computations suffices for all zones simply by changing in the tables the longitude values successively through 8°, 16°, 24°, etc., of longitude, respectively. (See Special Publication 59, U.S. Coast and Geodetic Survey.)

c. The military grid appears registered on gridded maps in two series of parallel lines at right angles to each other. On sheets of the terrain map (1:20,000), these lines form 1,000-yard squares. On sheets of the tactical map (1:62,500), these lines form 5,000-yard squares. The central meridian of the overlap between adjacent grid zones is the dividing line between the zones. Any map which falls within the 1° overlap between grid zones always shows in solid black lines the grid of the zone to which the map pertains. The grid of the adjacent overlapping zone may also appear registered by means of grid intersections (small crosses) on the face of the sheet and ticks around the border lines. The scheme is useful in effecting transition of data from one zone to another. The lines of the overlapping zone when needed may be struck in by simply joining the registration points. Since the grid lines of each zone are all parallel to the central meridian of the zone and since meridians converge to the poles, the lines of overlapping grids will always cross at distinct angles.

d. The distance of each north and south grid line, grid east of the zero point or origin of coordinates, is marked in thousands of yards along the south border of a gridded

map. The distance of each east and west grid line, grid north of the zero point or origin, is marked in thousands of yards along the west border of a gridded map. The numbers which identify the north and south grid line and the east and west grid line which intersect at or nearest to the southwest corner of a gridded map are written out in full in yards. In marking all other grid lines, the digits common to the sheet may be omitted. When the grid of an overlapping zone appears registered by ticks and grid intersection on a map, the ticks of the north and south and east and west grid lines, respectively, which intersect at or nearest to the southeast corner, are marked in full to yards. No other grid lines of the overlapping zone are marked.

e. By agreement with the War Department, sheets of the topographical atlas of the United States Geological Survey adopted as tactical maps will have the 5,000-yard grid registered by ticks along the borders.

NOTE: The above methods of showing grids on a map are followed by the Corps of Engineers in the reproduction of all gridded maps. There are maps in common use for school purposes, such as the Gettysburg map, on which only a local grid system is used. The reader should not confuse such a grid with the military grid system.

46. **Equatorial System.**—a. The equatorial system, using the same zones as the continental system, has the latitudinal origin at the Equator, and covers the area between the 7° N. and 28° N. parallels. The system is otherwise similar to the continental system. Tables and methods of computation for the equatorial system are found in Corps of Engineers publication "Grid System for Military Maps for 7° to 28° North Latitude."

b. In the overlapped areas below 28° N. in Texas and Florida, care must be taken not to confuse the two grid systems.

47. **Military Grid.**—a. **General.**—To make the reading of military maps easy, grids are printed on the map. The grid is simply a set of numbered north and south lines showing distance in thousands of yards east of the origin, and a set of numbered east and west lines showing distances in thousands of yards north of the same reference point. On a large-scale map (for example, 1:20,000 (par. 5)) these lines are 1,000 yards apart. On the medium-scale map (par. 5) the lines are 5,000 yards apart.

b. **Location by grid coordinates.**—Points are designated by coordinates simply by the intersection of the north-south grid lines (vertical lines) with the east-west grid lines (horizontal lines). Thus, in figure 29, location of the point A is indicated by the intersection of the 198 grid line and 262

grid line; the coordinates of the point therefore are (198-262). Note that distance east of origin is called the X-coordinate and is read first; and that distance north of origin is called the Y-coordinate and is read last. Beginners often make the error of reading the wrong coordinate first. One way to avoid this is to remember the key phrase "READ-RIGHT-UP." It often may be necessary to designate points which do not fall at the intersection of grid lines. For example, it is required to find the coordinates of point B in figure 29. If it is assumed that the sides of the grid square are further subdivided into 10 equal parts, it is seen that the point B is 8 of these parts east and 7 of the parts north of the south-west corner of the square in which B is located. The coordinates of the point B are therefore written (197.8-263.7). Often sufficiently close determination can be made by estimation. For example, CR (crossroads) 121 could be located by inspection at (196.4-263.4). Since on all commonly used large-scale maps the grid square measures 1,000 yards on a side, a reading to tenths (one decimal place) gives a location to the nearest 100 yards. A reading of hundredths (two decimal places) gives an accuracy within 10 yards. When the grid numbers have more than two digits, it is customary to drop off all but the last two digits. Thus, the coordinates of point B above may be written (97.8-63.7), or if greater accuracy is desired (97.80-63.70).

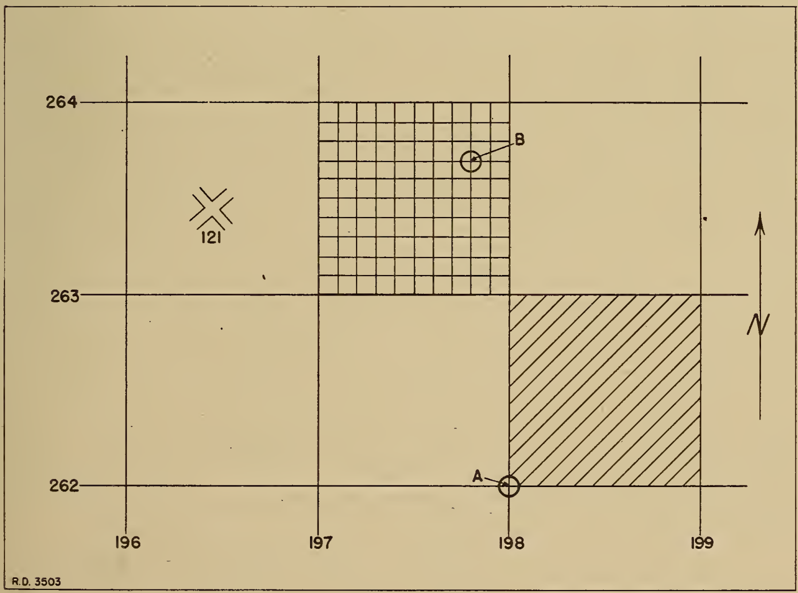


Figure 29.—Coordinates.

c. **Location by grid squares.**—When a point is easily identified such as a numbered crossroad or a town, it is necessary merely to refer to the southwest corner of the grid square in which it is located. For example, in Figure 29 crossroads 121 could be designated as CR 121 (96-63).

48. **Coordinate Scale.—a. General.**—In paragraph 47, the coordinates of point B were found by subdividing each side of the square (197-263) into 10 parts. This operation is used only for explanation and is too long and tedious for normal use. A grid coordinate scale or card as shown in (1) and (2), figure 30, permits finding these coordinates rapidly and easily. These cards may be made of cardboard, metal, or celluloid. For large-scale maps having grids 1,000 yards apart, lay off on the interior edges 1,000 yards to the scale of the map. Beginning at the vertex divide each 1,000 yards into 10 equal parts. This may be done by means of the graphical scale printed on the map. For medium-scale maps having grids 5,000 yards apart, lay off on the inner edges 5,000 yards to the scale of the map, and subdivide each 1,000 yard division into 10 equal parts as described above. The L-shape type is more convenient to use. However, the rectangular type (1) and (2), (Figure 30) may be readily improvised by taking any square piece of cardboard or heavy paper and laying it along the graphic scale at the bottom of the map, mark off one corner with 1,000 yard divisions, subdividing these into 100 divisions. (See Figure 31).

b. **To read coordinates of any point on map using coordinate scale.**—Required, to find coordinates of point P (fig. 30). First identify the square in which P lies and write the coordinates of the lower left (southwest) corner of the square thus (1,365-1,791), or, dropping off the first two digits as described in paragraph 47b, it could be written (65-91). Now place the coordinate scale with its horizontal (east-west) edge on the 1,791 grid line. Keeping this edge on the 1,791 grid line, slide the scale along until its north-south scale passes through the point P. The decimal portion of the X-coordinate is read on the horizontal (east-west) scale, where it is cut by the west boundary of the square (in this case the 1,365 grid line). The decimal portion of the Y-coordinate is read on the vertical (north-south) scale, at the point P. These readings are then filled in at the proper places after the coordinates already written down. Reading to the nearest 100 yards, the coordinates of P are (1,365.7-1,791.6) or (65.7-91-6). Reading to the nearest 10 yards the coordinates are (65.68-91.62). The coordinates of K are (65.25-92.48).

c. **To plot on a map any point whose coordinates are given.**—This process is the reverse of determining the coordinates of a point. For example, in Figure 30 let us assume that

it is required to plot the position of the point P whose coordinates are (1,365.68-1,791.62). Place the coordinate scale on the map as shown in position (1) in Figure 30. The position of P can be marked at once with a pin or sharp pencil.

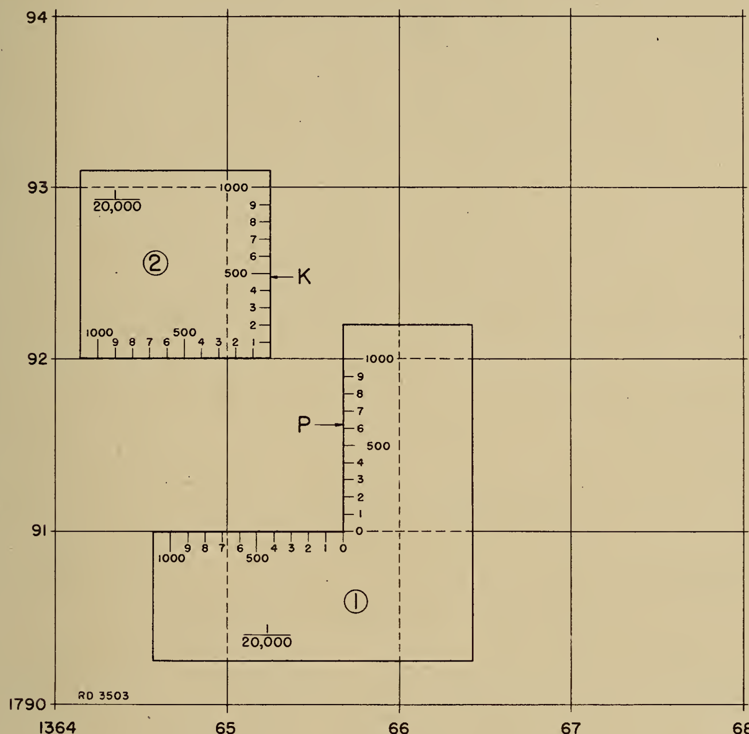


Figure 30.—Plotting point with coordinate scale.

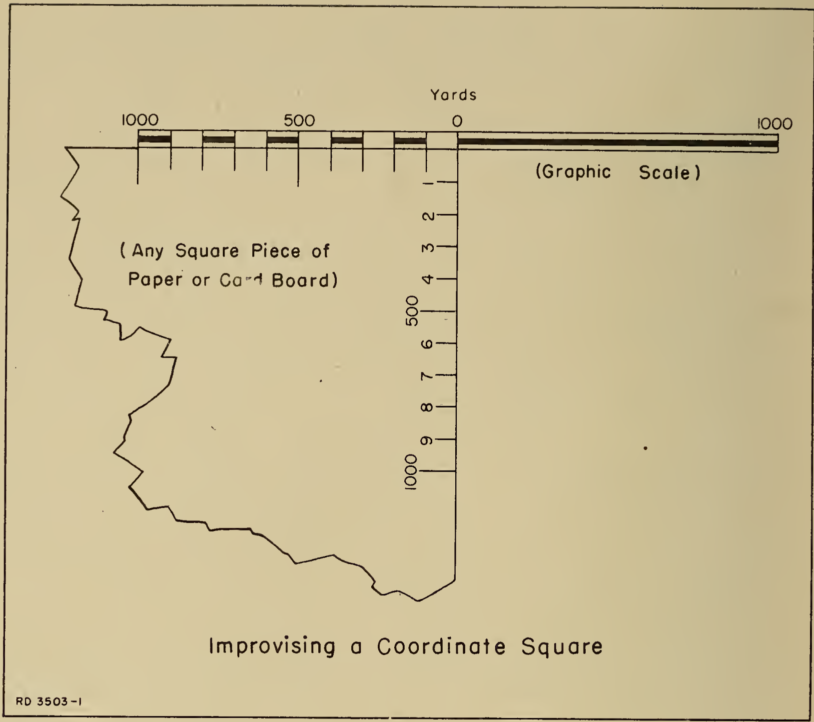


Figure 31.—Improvising a coordinate.

49. **Thrust Line.**—a. **General.**—A map-reference system of location known as a Thrust Line is similar to a German map-reference system called "stosslinie", which means thrust point. In one sense thrust line coordinates are simply rectangular coordinates with a "thrust line" substituted for a base position and base direction. This thrust line is any line designated by two points on the map. The points selected should be terrain features easily located both on the ground and on the map. The rear point is designated as the **point of origin.** The forward point is called the extension point and establishes the **direction** of the thrust line. The thrust line may be extended indefinitely in both directions along the axis, and generally points in the direction of the enemy.

b. **Plotting Thrust Line Coordinates.**—(1) The coordinates of any point are obtained by dropping a perpendicular from the point in question to the thrust line. The coordinates are then read by measuring the distance from the origin to the intersection of the perpendicular, and then from the intersection to the point in question. Distances forward of the origin are preceded by the letter F; distances back or to the rear of

the origin are preceded by the letter B. Similarly, distances to the right of the thrust line are designated by the letter R and distances to the left by the letter L.

(2) The unit of measurement can be established by the commanding officer when he designates the thrust line, or it may be established as standing operating procedure within the unit. Either map distance or ground distance may be used. If map distance is used, all maps concerned must be of the same scale or tedious calculations will be involved, but if ground distance is used, the coordinates will be the same on any representation of the area regardless of scale as long as the two points establishing the thrust line can be located. It is well to use a graphic scale of the selected unit as a ruler to measure distances on the map. The units to be used should always be clearly stated at the time the thrust line is designated.

(3) **Three digits** are required for each measurement; the **last digit** representing **tenths** of the unit of measurement, although **the decimal point is not shown.**

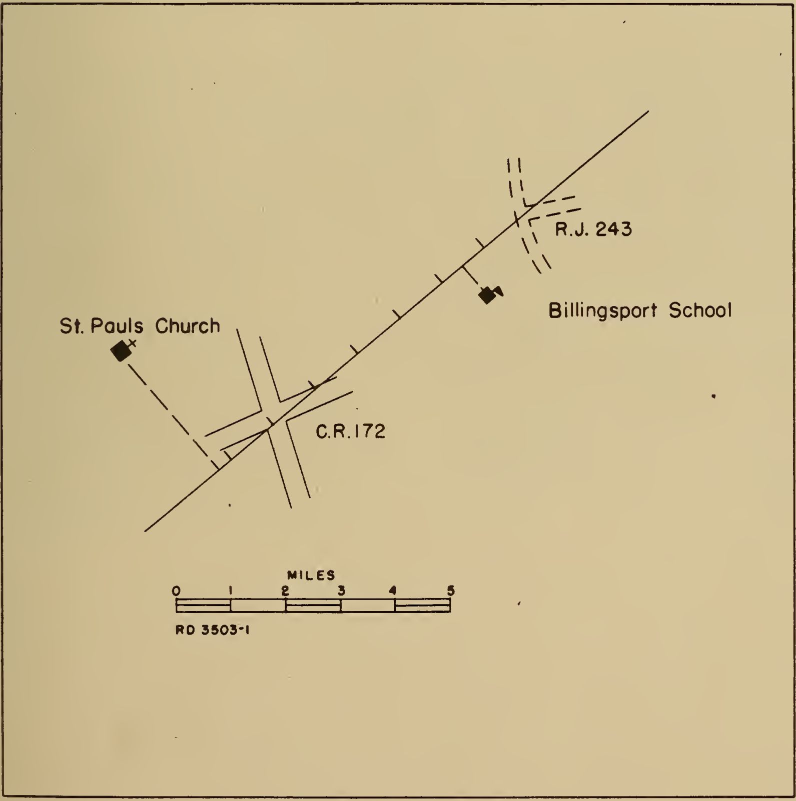


Figure 32.—Thrust line: From CR 172 to RJ 243.

The thrust line is drawn from CR 172, the origin, through RJ 243. This establishes the direction RJ 243 as forward (F). Distances measured from the origin in the opposite direction are back (B). The unit is stated as tenths of a mile. Therefore, the coordinates of Billingsport School are F045R008 (forward 4.5 miles, right 0.8 mile) and the coordinates of St. Paul's Church are B013L022 (back 1.3 miles, left 2.2 miles). Notice that the decimal is not written but inferred.

SECTION 7

ELEVATION AND RELIEF

50. General.—a. Ground form and elevation.—Up to this point the map has been regarded as a representation of a flat surface and only the horizontal position of features indicated thereon has been considered. A map to be of the greatest practical value must convey to the user a definite impression of ground forms (hills, ridges, and valleys) known as relief. This brings up the important subject of elevations. By elevation is meant the vertical distance of any specified point on the earth's surface above a selected reference plane which for most maps is mean sea level.

b. **Means of representing relief and elevation.**—Since a map is a plane surface, some type of conventional sign must be used in order to represent relief and elevation. On most modern topographical maps, this is accomplished by the use of contours. Other methods such as hachures and hill and valley shading are used but contouring is the most common and practical method.

51. Contours.—a. General.—Contours are the conventional signs drawn on a map to show the different ground forms. After practice with contours the map reader can not only visualize shapes of hills, mountains, and valleys, but can also find elevation of points and determine slope and visibility along given lines. A contour is a line drawn on a map which represents all imaginary line on the ground all points of which are at the same elevation. Figure 33 represents a hill in the middle of the ocean. The seashore line itself would be the base or zero contour. If the sea should rise 10 feet the new seashore line would mark the 10-foot contour. Similarly the next higher contour line would be marked for each rise in elevation of 10 feet. Figure 33 shows the successive increases in sea level which indicate contours. Figure 34 gives an oblique view of this same hill. From directly above, the hill would appear as in Figure 35. Wiping out the picture of the hill itself, it would appear on a map as in Figure 36 when indicated by contours alone.

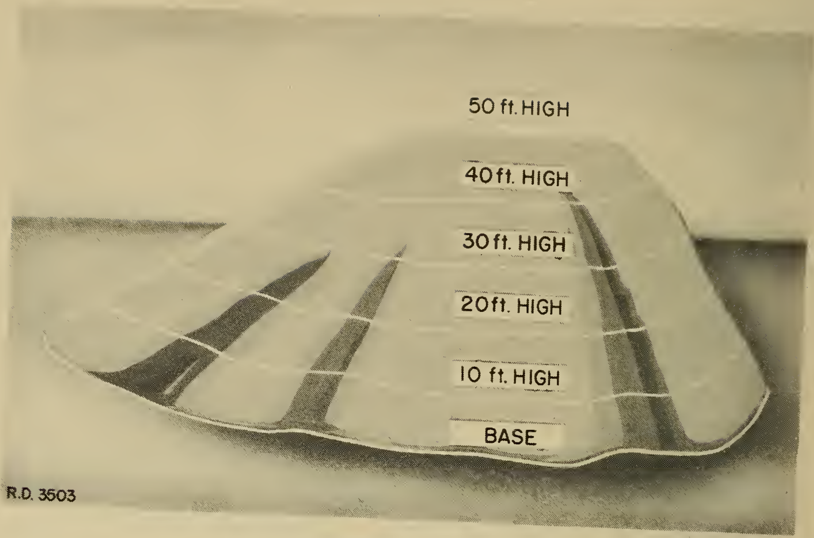


Figure 33.—Side view of hill.

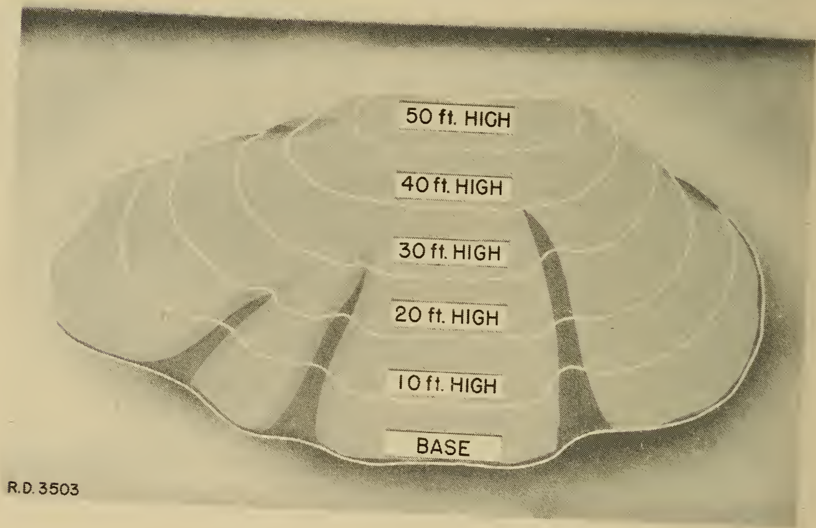


Figure 34.—Oblique view of hill.

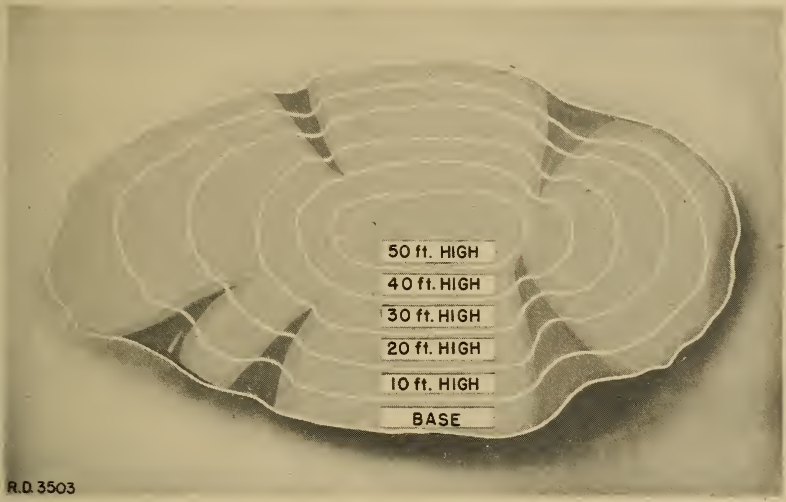


Figure 35.—Top view of hill.

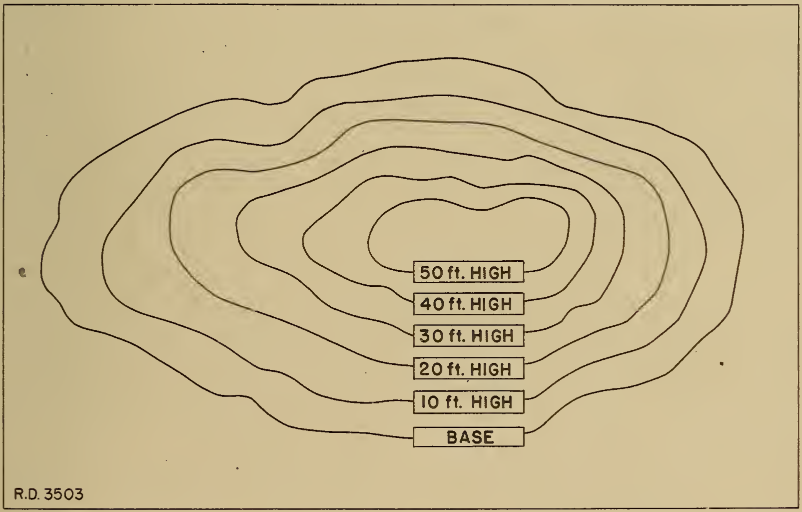


Figure 36.—Hill shown by contours.

b. **Characteristics.**—Figure 37 represents a number of more common ground forms as they are shown by contours. Looking at this figure it should be noted that—

(1) Contours have a characteristic appearance of a series of generally smooth curving lines (except in very rugged country).

(2) Elevation of contours above the reference plane (mean sea level) is shown by numbers usually in feet.

(3) At A, B, and C are contours which are closed curves, indicating either hilltops or depressions. Since the contour numbers increase as these points are approached it is apparent that A, B, and C are actually on hilltops.

(4) Contour at A, being nearly circular, indicates the top of a peak or knob, whereas the elongated contour at C indicates the crest of a sharp ridge.

(5) Though all contours are closed curves, most of those shown do not close within the limits of the map sheet. The 200-foot contour runs off the sheet at D-D and closes just outside, as indicated by the broken line. It runs off again at D′-D′ and closes beyond limits of the sheet.

(6) On the line AA′ there is a uniform slope. This is indicated by the equally spaced contours. On the line BB′ there is a concave (sway-back) slope since the contours are close together at the top and farther apart at the bottom. On the line CC′ there is a convex (humpback) slope. At B there is a steep slope while at B′ there is a gentle slope. The representation of these slopes by means of profiles is further illustrated in Figure 45. (For construction of profiles see paragraph 64.

(7) Contours do not touch each other except at E, which indicates a vertical cliff.

(8) At the points marked X is seen the characteristic V-shape of valley or streamline contours, and at those points marked U, the U-shape of ridge contours. The closed ends of the V's point upstream and those of the U's downhill.

(9) At A′ is shown the characteristic M-shape appearance of the contour at a Y-stream junction.

(10) Rain falling at I runs down the slope normal to the contours, entering the drainage line near G, and ultimately leaving the area by the main stream at J. The line of the spur AA′ is the divide between the two tributary streams. Rain falling at K, just east of the divide flows into the eastern tributary. The divide between any two adjacent valleys is easily traced out.

(11) Point S is a saddle, a depression or low point in a ridge or line of hills. Note the characteristic shape of the contours. Saddles occur frequently.

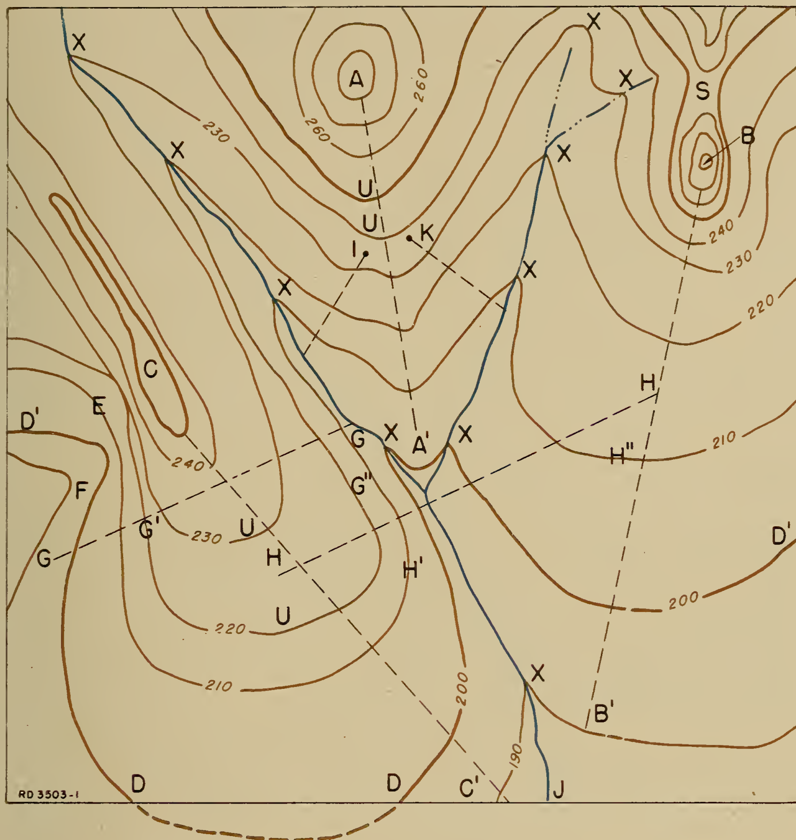


Figure 37.—Characteristics of contours.

(12) Adjacent contours in a water-worn terrain resemble each other. This is the same as saying that changes in the form of the ground are gradual. This characteristic may be noted at many places, as on the ridge lines at AA′ and BB′.

c. **Summary.**—Briefly summarized, contour characteristics previously discussed and illustrated are—

(1) A contour is a line on a map joining points of equal elevation.

(2) Contours are spaced at uniform vertical intervals.

(3) A small closed contour indicates a hilltop or a depression when so marked by the conventional sign.

(4) Every contour is a continuous closed curve, on or off the map.

(5) Spacing of contours indicates steepness of slopes. This spacing also indicates nature of slope, whether uniform, concave, or convex.

(6) Contours do not touch or cross each other, except in the unusual case of cliffs.

(7) Valleys are usually characterized by V-shaped contours, and ridges by U-shaped contours.

(8) Adjacent contours resemble each other.

52. **Contour Interval.**—a. The contour interval, or the vertical distance in feet between one contour and the next is stated as marginal information, usually under the scale at the bottom of each map. This interval differs according to the topography of the area mapped and the scale of the map; in a flat country it may be as small as 1 foot; in mountainous region it may be as great as 250 feet.

b. For military use it is necessary that the various sheets of a map of any given area have a common scale and contour interval or intervals that match. In order that peacetime practice throughout the United States be consistent, the War Department (AR 300-15) and the United States Geological Survey have adopted the following contour intervals for standard quadrangle maps. The intervals in general conform to contour intervals found on most existing topographic maps.

(1) Contour intervals of 5, 25, 50, or 100 feet in the States which lie all or mostly west of longitude 103° as follows: Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, Montana, Wyoming, Colorado and New Mexico.

(2) Contour intervals of 5, 10, 20, 40, or 100 feet in the States which lie all or mostly east of longitude 103°. The 5-foot contour intervals is used only on large-scale maps of limited areas.

c. On most maps every fifth contour line is made heavier than the others and is accompanied by figures showing the altitude at convenient intervals.

53. **Elevations of Important Features.**—The elevations of important features such as road junctions, summits, and surfaces of lakes, called spot heights, and those of bench marks are given on the map in figures to the nearest foot. More exact altitudes of bench marks are published in bulletins that are issued by the Geological Survey and the Coast and Geodetic Survey. On coastal charts the datum is mean low water.

54. **Logical Contouring.**—a. In mapping, contouring may be done by the topographer in the field by one of several methods:

(1) He may actually run out the location of the

contours on the ground. This method is applicable to large-scale maps when great accuracy is desired and the expenditure of time and labor is economically justified.

(2) He may run out enough contours to define the ground forms and interpolate between them by eye.

(3) He may run out only stream and ridge lines, getting elevations on these lines at each change of slope or ground form. Such elevations defining the ground forms are known as "critical elevations." The contours may then be sketched in the field by eye between critical elevations. This method is the cheapest, quickest, and most commonly used.

b. Logical contouring may best be explained by an illustrative example. In Figure 38 ① critical elevations have been measured by the topographer. The problem is to interpolate 10-foot contours so that the ground forms depicted will be logical.

(1) First, along the main stream, interpolate the elevations of all stream junctions not shown by assuming that the stream has a uniform slope between critical points. For example, there is a stream junction of unknown elevation between elevations of the stream of 91 and 97 feet, respectively. Between these two points the stream rises 6 feet. Because the stream junction, the elevation of which is sought is approximately half the distance measured along the stream between elevations 91 and 97, it is assumed that the stream has risen to that point only one-half of 6, or 3 feet. The elevation sought is therefore 94 feet.

(2) In this way, interpolate elevations which are multiples of 10 feet on all the streams. These are the points where contours cross the stream and are shown as V-shaped marks pointed upstream as in Figure 38 ②.

(3) By interpolation between critical elevations determine where 10-foot contours trace the ridges and indicate by slightly drawn U's. Since hills are normally rounded at top and slope off gradually at the bottom, contours will have slightly closer spacing on the rise than at the crest or bottom.

(4) Consider the importance of all critical points in relation to each other, remembering that ground forms between generally parallel streams are in the form of ridges, terminating in spurs or noses.

(5) Starting at the lower end of the main streamline and using the drainage system as a skeleton upon which to shape the contours, connect all interpolated points of the same elevation with a smooth, curved line, continuing each contour line until it runs off the map or closes on itself.

(6) Every fifth contour (starting from O) should be made heavier than the rest and should have the elevation written on it.

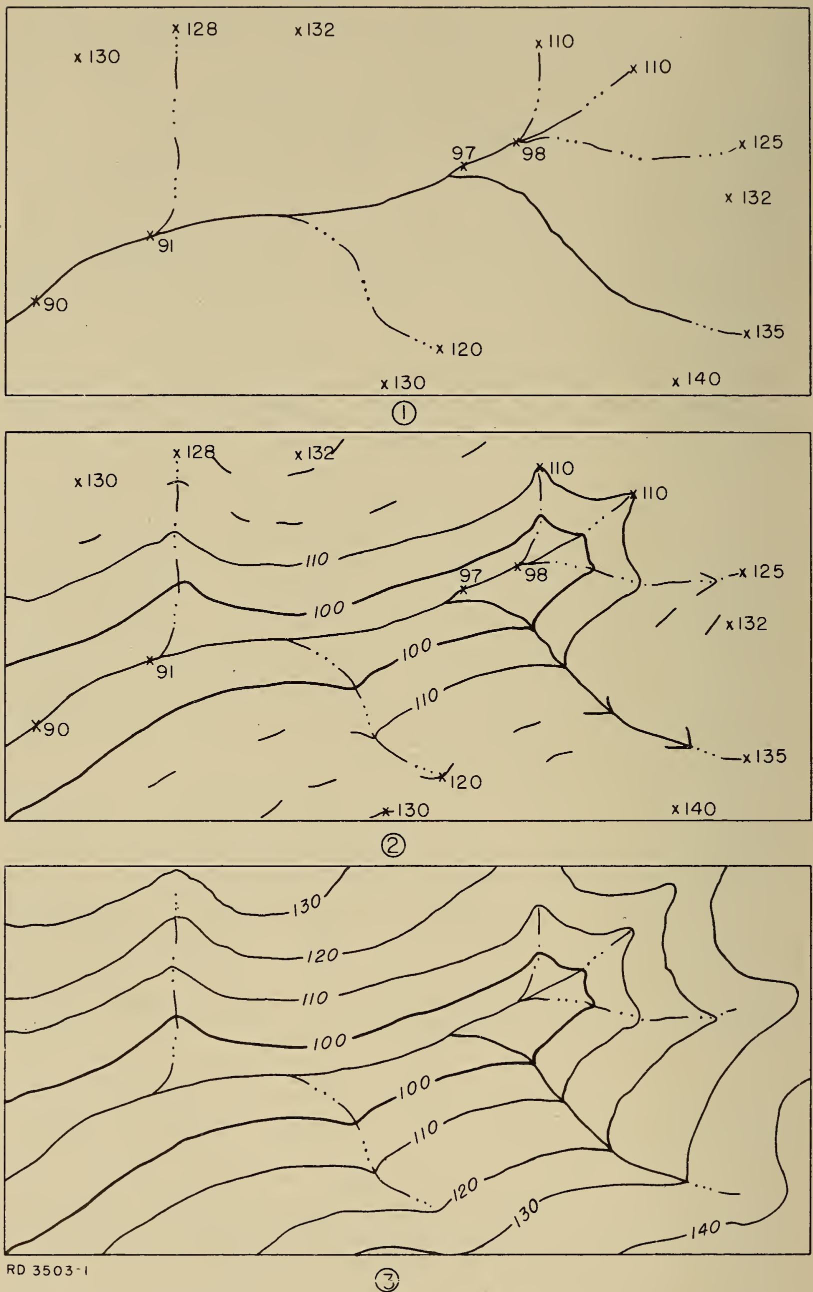


Figure 38.—Method of drawing contours by interpolation on drainage net where elevations are given.

c. **Contouring a saddle.**—One of the few ground forms that may cause difficulty in contouring logically is the saddle. In order to recognize the existence of saddle when only the critical elevations are given, remember that five points are needed to determine a saddle and that a saddle is the low point between two high points and is also the high point between two low points. These five points are connected in a diamond or kite-shaped pattern and interpolations are made along all these lines. If this method is followed as illustrated in Figure 39 it greatly simplifies the contouring of saddles.

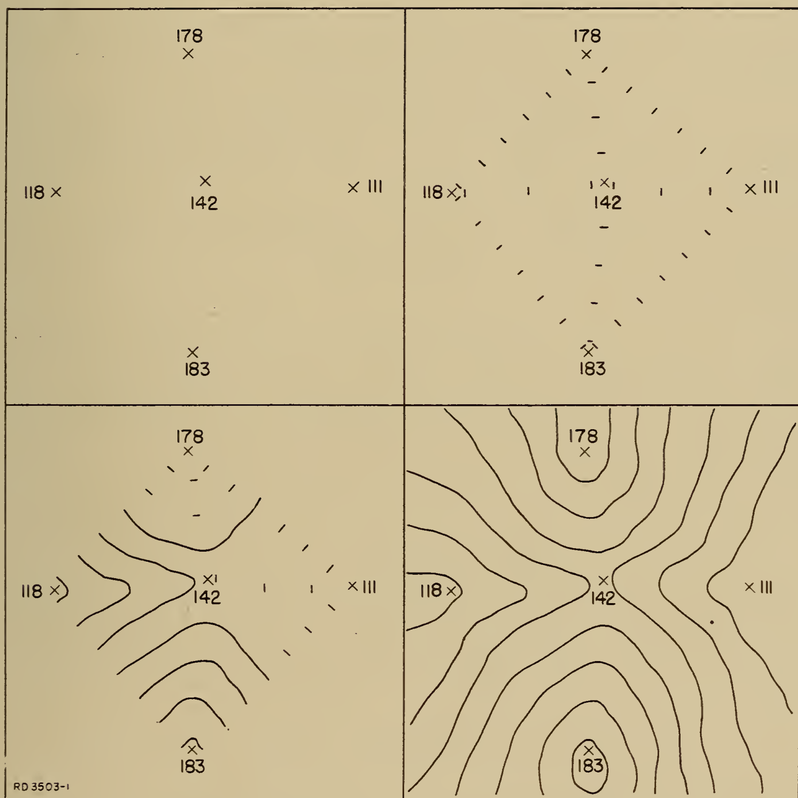


Figure 39.—Contouring a saddle.

d. The contours should be sketched while in the field. However, if enemy action or other cause makes this impossible, contours may be interpolated in the office, preferably with the aid of aerial photographs and a stereoscope, provided that critical points have been adequately determined.

55. **Determination of Elevation.**—a. In the discussion in paragraph 53, elevations of important features on the map were determined by their spot heights. Where accurate elevations of other points are desired, some means of interpolation between contours becomes necessary. In the following procedure the refinement is for theoretical purposes only. Any interpolation from contours is an approximation upon which undue refinement may be misleading.

b. Refer to the margin of the map. To determine the elevation of any specific point, proceed as follows (fig. 40):

(1) If the point falls on a heavy contour, it is only necessary to follow that contour until the elevation appears and read it. For example, the elevation of the point B in the figure is read directly as 1,300 feet.

(2) If the point falls on a light contour, the elevation is found by reference to the adjacent heavy numbered contour lines and interpolating. For example, the elevation of the point A is 1,260 feet.

(3) When the point lies between two contours as at C in Figure 40.

(a) Find the elevation of the nearest contour line.

(b) Measure the shortest distance between the two adjacent contours along a line passing through the point C.

(c) Measure the distance along this line from the point in question to the nearest contour.

(d) Solve the following equation:

$$\frac{\text{Distance from point to nearest contour}}{\text{Distance between contours}} \times \text{contour interval}$$

= difference in elevation between point in question and the nearest contour. Since the distance between adjacent contours at this place is 375 yards and since C is 125 yards from the nearest contour (the 1,260 contour), entering the equation given above,

$$\frac{125}{375} \times 20 \text{ feet} = 6\tfrac{2}{3} \text{ feet.}$$

Taking the nearest whole number of feet (7), the elevation at point C is 7 feet less than the elevation of the nearest contour, or 1,260 — 7 = 1,253 feet. If the nearest contour is of lower elevation than the point in question, the difference in elevation must of course be added.

(For all practical purposes the interpolation between contour lines may be estimated by eye without recourse to the above method.)

(4) When a point, the elevation of which is required, lies within a closed contour forming the top of a hill, ridge, or nose, or the bottom of a depression, only an approximation of its actual elevation is possible. Consider the elevation in respect to probable ground form obtained as indicated by the spacing of adjacent contour lines.

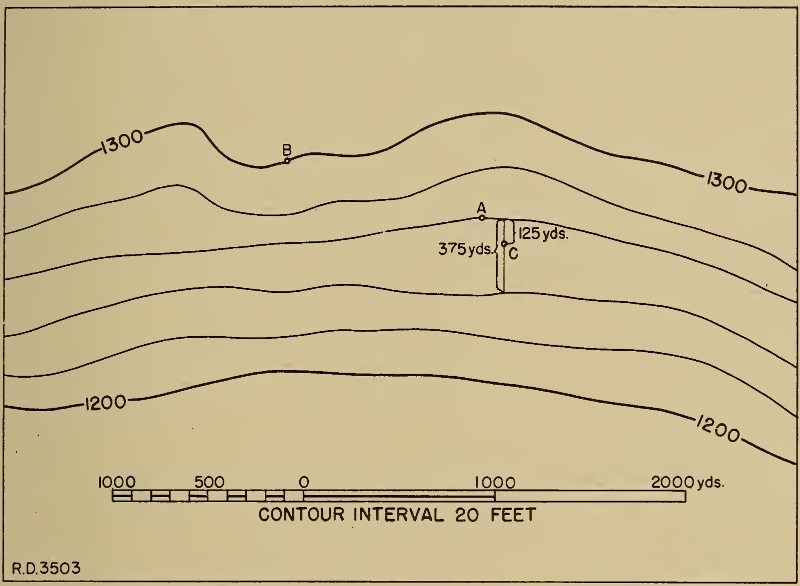


Figure 40.—Determination of elevation on contoured map.

56. Ridge Lining and Stream Lining.—a. **Purpose.**—In order to emphasize the basic structure or master lines of the terrain of a given area, a system known as ridge lining and stream lining is often used. On a map or an aerial photograph thus ridge lined or stream lined, the great mass of detail which may tend to confuse may be neglected for the moment, and those basic structures such as stream systems, ridge lines, and key features can be emphasized. Three steps may be followed in this process.

b. **Stream lines.**—Study the map or aerial photograph and select the main streams and their tributaries. Emphasize them, preferably by drawing over them in blue, and thus cause the drainage system to stand out.

The drainage net is the key to the topography.

c. **Ridge lines.**—Draw a line down the main ridges. This should be done preferably in red so as not to obscure features lying under the lines. Then select the minor ridges and trace their ridge lines in a similar manner. The number of minor ridges to be included will depend upon the emphasis desired. In drawing ridge lines it is not normal to carry them all the way to the stream. A good system is to stop at the

beginning of the flood plane as shown by the increase in space between contours. It will be noted that the tendency at first is to mark isolated ridges, whereas the ridge lines should form a **connected** structure. If all the ridge lines in an area are drawn, it usually will be found that they join together into a systematic branching structure like the fingers of a hand or the backbone and smaller bones of a fish. This structure is similar also to the branches of streams; in fact the branches are fingers of the two systems fitted into each other. Ridge lines **do not** cross streams. Figure 41 shows a portion of a contour map which has been ridge lined. Note how the main drainage system and the main ridge lines stand out.

d. **Emphasized contours on contoured maps.**—Certain contours may be emphasized by use of thicker lines, and it is customary to do this at regular intervals to facilitate the reading of contour maps. Likewise, commanding elevations may be brought out by coloring the map area between selected contours.

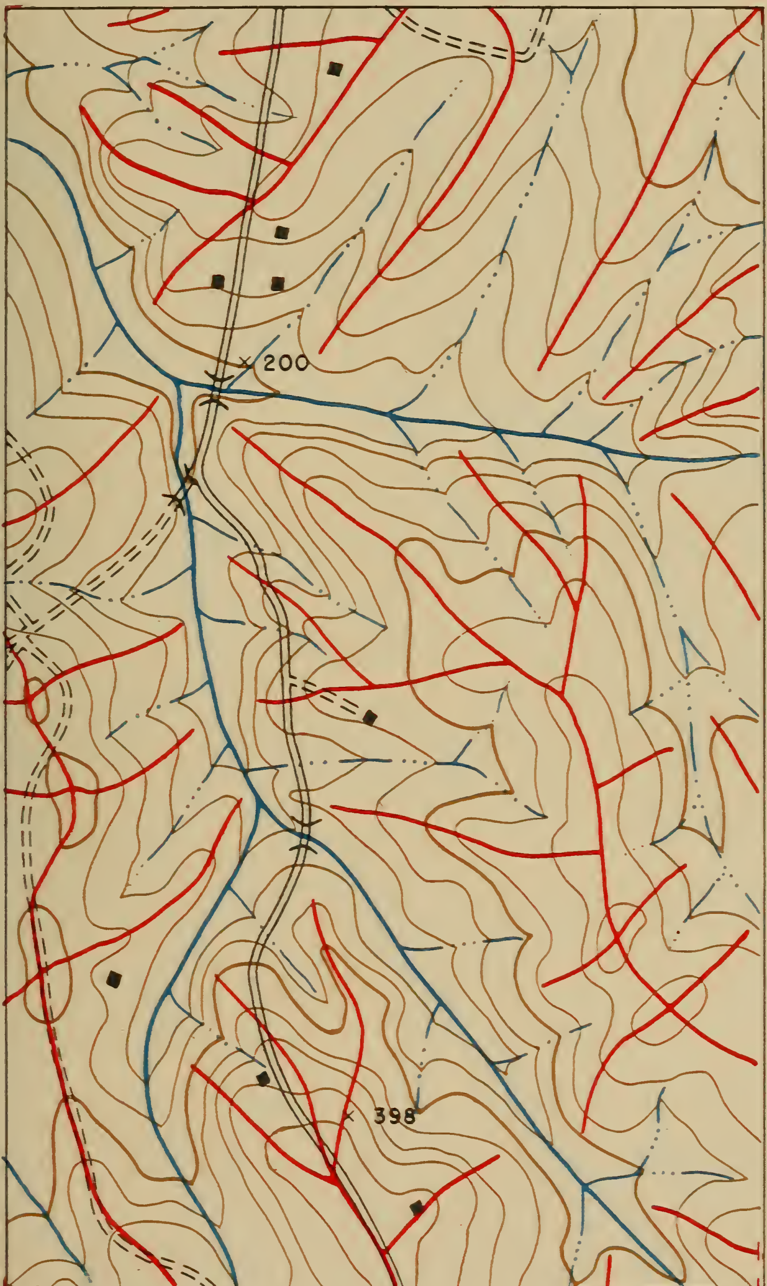


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Figure 41.—Ridge and drainage lines.

SECTION 8

SLOPE, PROFILE, AND VISIBILITY

57. **Slope.**—The inclination of the land surface relative to a horizontal plane is the slope, and slope is a function of two factors—horizontal distance and vertical distance. Two points are therefore necessary to determine these factors. The vertical distance is the difference in elevation of the points and on a contoured map may be interpolated from the contours. The horizontal distance is scaled from the face of the map. Along a straight line it is the scaled length of the straight line. Along a meandering stream, irregular road, or broken line, it is the scaled length of the meander line or other irregular distance under consideration. Both horizontal and vertical distance must be expressed by the same units, preferably feet. Slope may be computed or measured and expressed in terms of percent, mils, degrees, or as gradient. The slope of roads and railroads is referred to as grade. While the most commonly used method of expressing slope is by percent, the advanced map reader should be familiar with other methods.

58. **Slope in Percent.**—Percent is the most convenient and commonly used method of expressing slope. A slope of 1 percent is a slope which rises vertically a distance of one unit in a horizontal distance of 100 units or one which has this rate of rise (Figure 42). A 2-percent slope rises two units, a 3-percent slope rises three units, and so on, in a horizontal distance of 100 units. The value in percent of any slope is the number of units which it rises vertically in a horizontal distance of 100 units. Thus a rise of 26.8 feet in a horizontal distance of 100 feet is a slope of 26.8 percent.

59. **Slope in Mils.**—The mil is a unit of angular measurement. A true mil is an angle which subtends an arc of unity at a radius of 1,000 units (Figure 42). A 2-mil slope subtends an arc of two units, a 3-mil slope subtends an arc of three units, and so on, at a 1,000-unit radius. The value of slope in mils is therefore a function of the angle of slope. The vertical rise of a mil slope is not exactly equal to the subtended arc, the vertical rise of a slope of 2 mils is not exactly twice the vertical rise of a slope of 1 mil, and the variation increases with the angle of slope. However, for slopes up to 350 mils, the variations are inappreciable and may be disregarded for average purposes. Thus a slope which rises 268 units in a horizontal distance of 1,000 units is a slope of 268 mils (Figure 42). Slopes may be measured with instruments graduated in the arbitrary mil which is 1/6400 of a circle. For ordinary slopes the results would not differ appreciably from the value in true mils, of which the circle contains approximately 6,283.

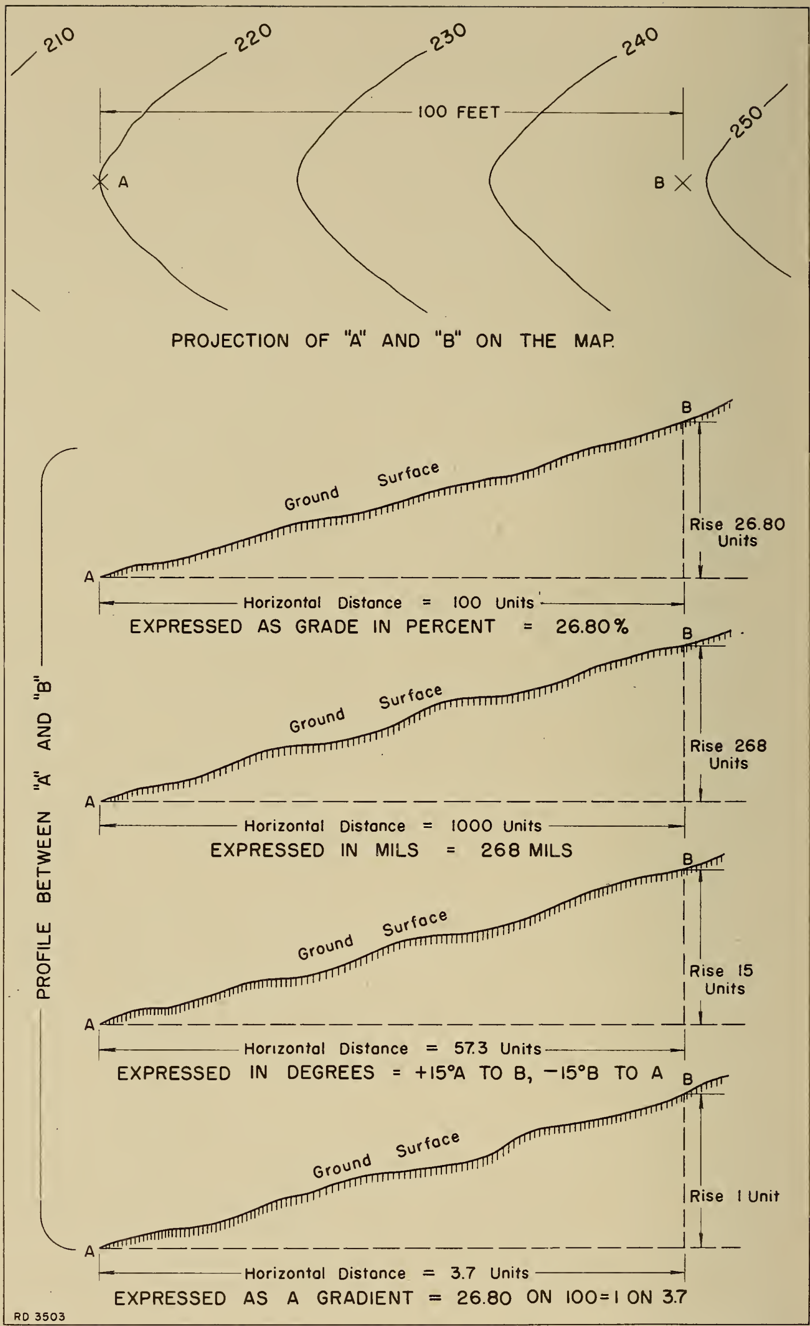


Figure 42.—Determination and expression of slope between two points "A" and "B" on map.

60. Slope in Degrees.—Many instruments for measuring slope are graduated in degrees. The degree is a unit of angular measurement and is 1/360 of the circle. A degree is an angle which subtends an arc of unity at a radius of approximately 57.3 units (Figure 42). A 2° slope subtends an arc of two units, a 3° slope subtends an arc of three units, and so on, at a 57.3-unit radius. The value of slope expressed in degrees is therefore a function of the angle of slope (Figure 42). The vertical rise of a degree slope is not exactly equal to the subtended arc, a slope of 2° is not exactly twice the vertical rise of a 1° slope, and the variation increases with the angle of slope. However, for slopes up to 20° the variations are negligible and may be disregarded.

61. Gradient.—The gradient is the unit usually used in the measurement of steep slopes. It is the ratio of vertical to horizontal or of horizontal to vertical distance (Figure 42). The manner of expressing this ratio has not been standardized. Two methods are in common use as follows: A gradient of 1 on 3.7 and a gradient of 3.7 to 1.

62. Slope Between Two Points on Map.—a. Subtract the elevation of the initial point from the elevation of second point to determine the difference in elevation or vertical rise.

b. Scale from the map the horizontal distance between the two points along the line whose slope is to be determined and express in the same units of measurement, preferably feet.

c. Compute the value of slope from the appropriate one of the following formulas:

$$\text{(1)}\quad \text{Percent} = \frac{\text{difference in elevation} \times 100}{\text{horizontal distance}}$$

$$\text{(2)}\quad \text{Mils} = \frac{\text{difference in elevation} \times 1{,}000}{\text{horizontal distance}}$$

$$\text{(3)}\quad \text{Degrees} = \frac{\text{difference in elevation} \times 57.3}{\text{horizontal distance}}$$

$$\text{(4)}\quad \text{Gradient} = \frac{\text{difference in elevation}}{\text{horizontal distance}}$$

expressed as a fraction reduced to simplest terms.

63. Average Slopes.—In determining slopes by the methods and formulas described, it should be remembered that the result expresses the slope of an inclined plane surface, whereas the actual surface of the intervening ground may vary quite irregularly up and down. It is therefore customary to refer to slopes thus determined between points over broken terrain or irregular surfaces as "average slopes."

64. Profile.—a. **General.**—The most satisfactory way of showing the slope of any line on a map is by drawing its profile.

A profile between two points is the line (usually irregular) of intersection of an imaginary vertical plane cutting the earth's surface between two points. For example, in Figure 43 imagine a vertical plane passed from above through the earth between the points A and B, and the front half of the hills and the ridges removed, just as a cook passes a knife through a cake and removes half. The outline of the surface of the remaining half would be its profile as represented in Figure 43 ②. Profiles are also a means of determining the visibility or the defilade of points or areas from any selected point on a map. Visibility is discussed in paragraph 65.

b. **To draw profile between two points.**—Figure 43 represents a portion of a contoured map. It is desired to construct the profile of the ground represented by the map between the points A and B. Proceed as follows:

(1) Connect points A and B by a straight line and assume that a vertical plane is passed through this line.

(2) Take a piece of cross section paper or any paper which has parallel lines equally spaced; cut or fold the paper along one of these lines.

(3) Refer to map and determine the highest and lowest elevation along the line AB; number the spaces on the paper to correspond with the elevations on the map beginning with the highest elevation toward the top edge of the paper (fig 43).

(4) Place the top edge of the paper along the line AB and where the edge intersects each contour, drop a perpendicular to the horizontal line on the paper corresponding to the elevation of the contour being considered. Proceed in the same manner with each contour.

(5) Connect the points of intersection of the perpendiculars with the lines on the paper with a smooth, curved line. This will represent the profile except between adjacent contours of the same elevation which require the determination of intermediate elevations.

(6) Where the line crosses a crest or a depression an elevation number on the map is sometimes found to assist in completing the profile. Where such elevation numbers are missing, interpolate necessary elevations from the spacing of the contours.

(7) When a profile is desired of an irregular line on the map, such as a road or trench, divide it into a series of sections approximately straight and plot as directed above, turning the paper at each angle to make a continuous profile.

c. **Vertical scale.**—Profiles usually have an exaggerated vertical scale in comparison with the horizontal scale which ordinarily is the same as that of the map as shown in Figure

43. In the figure, the lines on the paper could represent 10-foot elevations indicated, or they could represent 5-foot elevations, thus further exaggerating the profile as desired. For constructing profiles, use of cross section paper will be found most convenient since the vertical lines assist in dropping the perpendiculars to the horizontal lines representing the contour elevations.

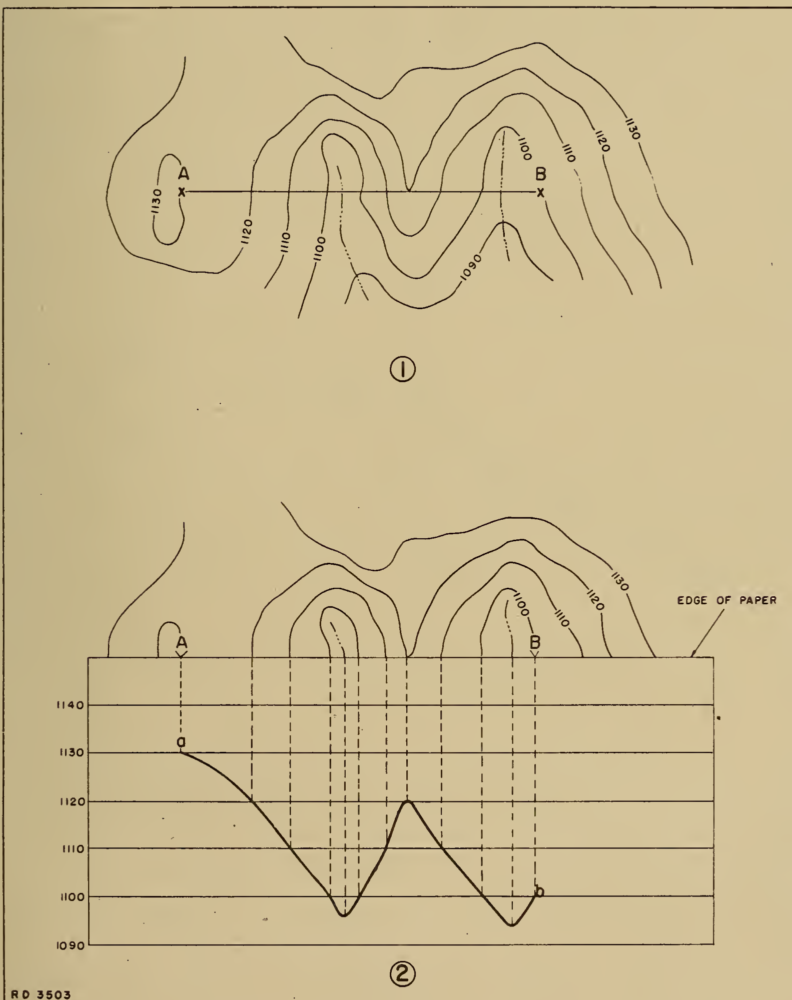


Figure 43.—Construction of a profile.

65. Visibility.—a. General.—One of the important uses of maps for military purposes is to determine whether a point, a route of travel or an area is visible from a given point or position. The extent of the area visible affects selection of targets, siting of weapons, and location of defiladed area or dead space (Figure 44). There are various methods of solving visibility problems but only the ones more commonly used will be covered in this text.

b. **Inspection.**—Many problems of visibility may be solved by inspecting the map, and determining from the contours the ground slope represented. The representation of ground slopes by contours is described and illustrated in paragraph 51. For example, in Figure 44 it is evident by inspection that an observer at B cannot see the ground at A, this being a convex or humpback slope, while an observer at C can, this being a concave or swayback slope.

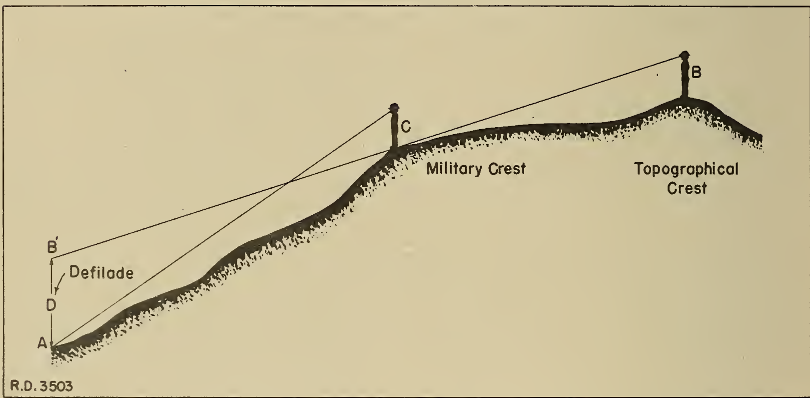


Figure 44.—Defilade.

c. **Profile.**—In paragraph 64 it was learned how to construct a profile between two points such as AB on Figure 43. Suppose it is required to use the profile method to determine what points along the line AB are visible from an observer at A. Construct a profile along the line AB as described in paragraph 64. It is evident in Figure 45 that the portion of the profile that is shaded is not visible from an observer at A.

d. **Hasty profile.**—Many problems of visibility may be solved without drawing a complete profile. In such cases only the critical points which may affect the visibility are plotted, such points being first determined by inspection.

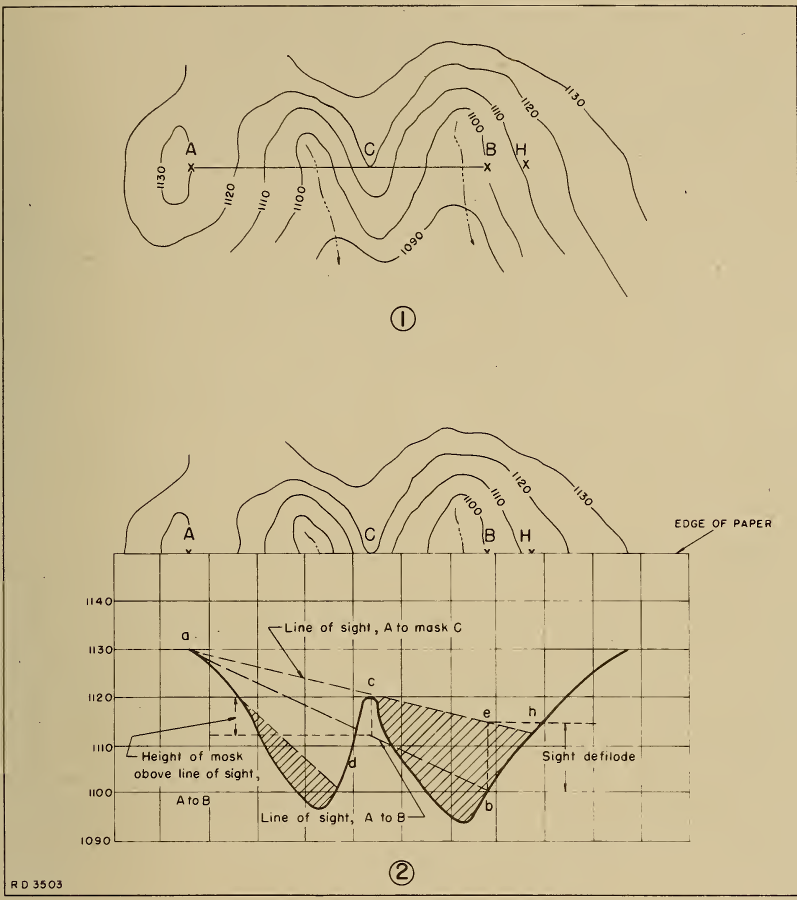


Figure 45.—Determination of visibility by profile method.

These points would be the position of the observer's eye, the probable masks (hills and ridges), and the point where visibility is to be determined. This is illustrated in Figure 46 which represents a portion of a contoured map. It is required to determine what an observer can see along the line AP from various points along this line, assuming trees and other vegetation do not interfere. It is evident that while at A the observer can see only point B and point F. From B he can see A, C, E, and F, but is unable to see points D and P. This can be continued for other points.

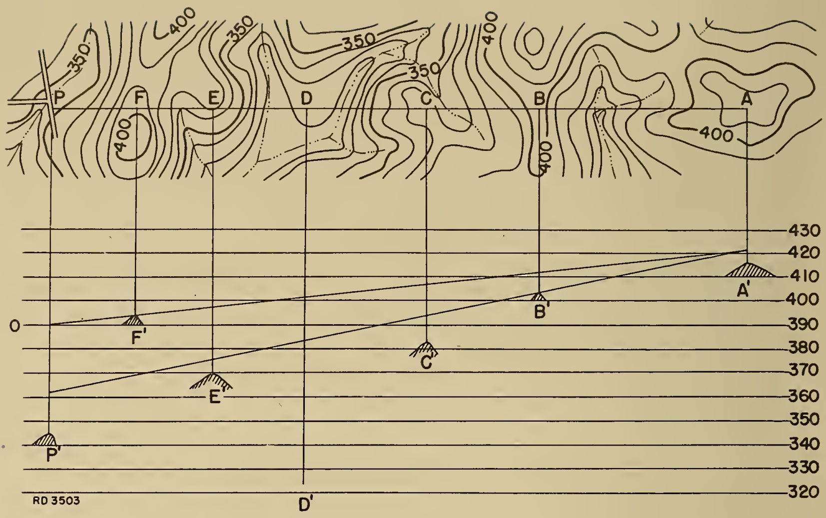


Figure 46.—Determination of visibility by hasty profile method.

e. **Defiladed Areas.**—It is often desirable to know the area that is defiladed from observation from a certain point. This defiladed area may be plotted on the map by extending a series of lines in a spoke-shaped pattern from the point in question. Profiles may then be constructed along each of these lines or radii. The line of sight from the point of observation is then drawn in and the defiladed or dead space along this line is then projected back onto the line on the map. The series of defiaded lines of sight are then connected logically with a smooth, curved line and the total defiladed area shaded or crosshatched. (See Figure 47).

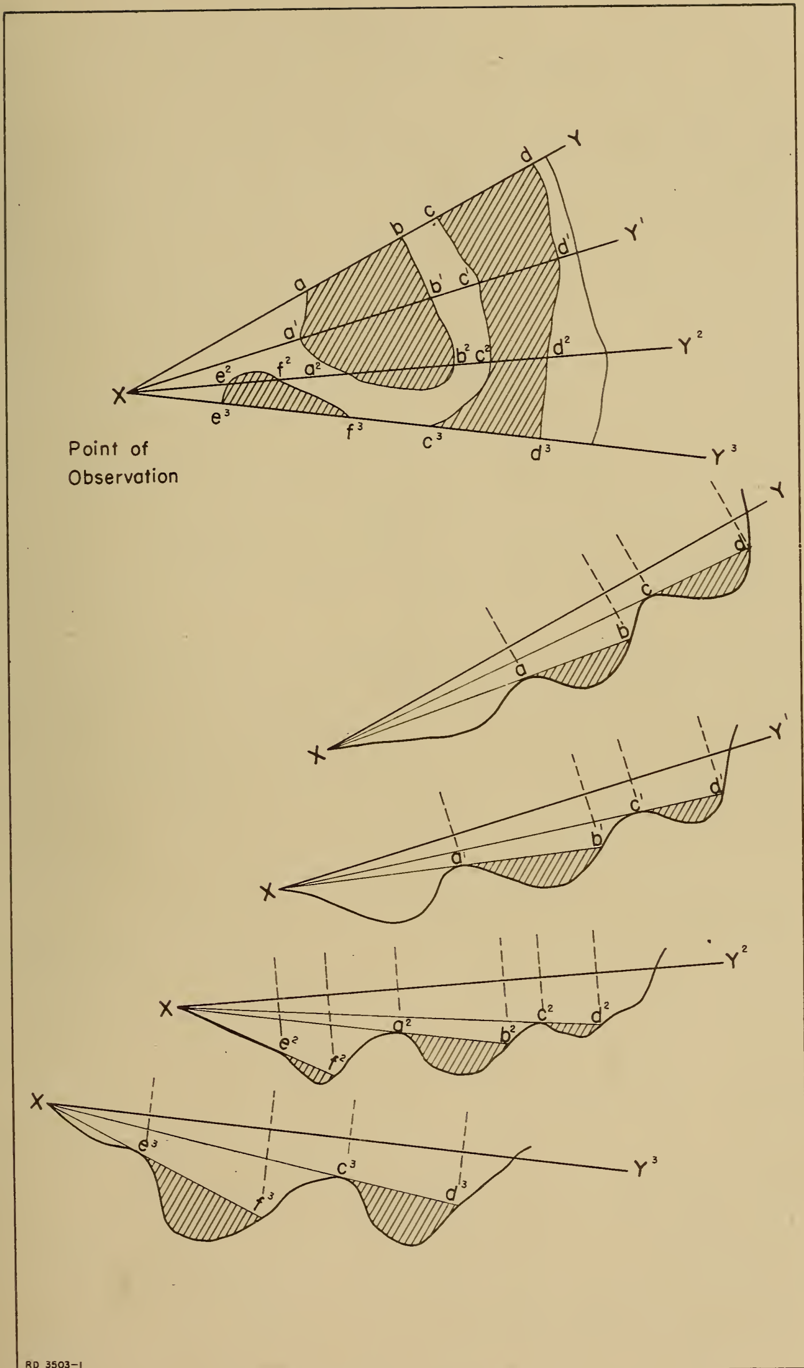


Figure 47.—Defiladed areas.

SECTION 9

MAP READING IN THE FIELD

66. **General.**—All students should keep in mind the importance of being able to read maps accurately and quickly in the field. Many disastrous mistakes have resulted from a lack of ability to read maps. To be able to read a map properly in the field, the student should be familiar with all material covered in the preceding sections. He should keep in mind that the map and aerial photograph are often the only means available for studying distant or inaccessible areas. He should always take his map into the field with him and constantly refer to it. He should keep his movements plotted on it, especially when operating over unfamiliar territory, and verify his location at every opportunity. He should practice until it is possible for him to secure a clear and accurate picture of the ground from the information given on the map. In addition to material in preceding sections, a few aids to his map reading ability are orientation, use of compass, determination of distance, and names by which ordinary features of the ground are known. A brief description of each of these follow.

67. **Orientation.**—a. **Definition.**—A map is oriented when, in a horizontal position, its north point points north and all lines of the map are parallel to the corresponding lines of the ground. A map reader is oriented when he knows his position on an oriented map and the cardinal directions on the ground. A map will be of small use in the field unless its possessor can orient himself readily. It follows that ready command of the simpler methods of practical orientation is of prime importance to the student of map reading.

b. **Method of map orientation.**—(1) **Inspection.**—Figure 48 shows how a map may be oriented by carefully observing road system and features in immediate vicinity. It will be noted that the map has been rotated horizontally until the road on the map parallels the road on the ground, care being used to see that positions of nearby ground features are in similar relation to their corresponding conventional signs as shown on the map. This is the most practical method of ordinary purposes and may be used as a rough check on more accurate methods.

(2) **Compass.**—Magnetic north is shown on most maps and is also indicated in the field by the north end of the compass needle. Figure 49 illustrates use of this method. Either prolong magnetic north line or draw a line parallel to it. Then place compass on map with north point of compass case on this line. Rotate map horizontally until north end of needle coincides with north point of the case. Map is now oriented.

On gridded maps the compass may be placed on the Y grid line and map rotated until the compass needle points to prevailing magnetic north as set forth in map marginal data.

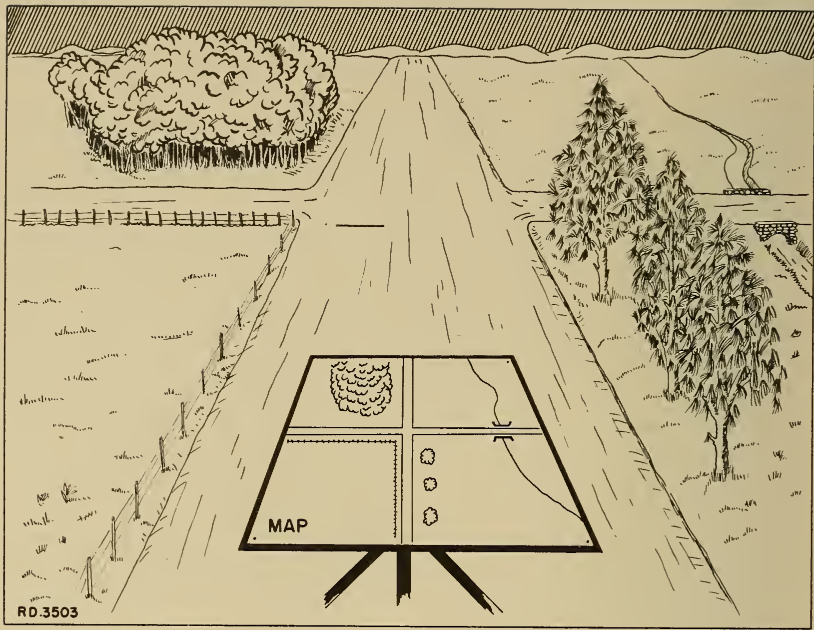


Figure 48.—Orienting map by inspection.

(3) **By means of a distant point when observer's position is known.**—A third method of orientation where a compass is not available and where there are no nearby features suitable for orientation by inspection is illustrated in Figure 50. Place a pin at observer's position on map. This may be found by reference to the fence corner (Figure 50). Place another pin on the map location of some well-defined point such as the church. Holding map horizontal, sight at church on the ground along the line of pins. Map is now oriented. A more precise orientation is secured if more than one point can be used. Once the map is oriented, approximate map location of a target or other point may be determined as follows: keeping map in oriented position, sight over pin at observer's position toward designated point and place a pin on line of sight. From a study of the map or by estimation or measurement of the distance fix location of the point.

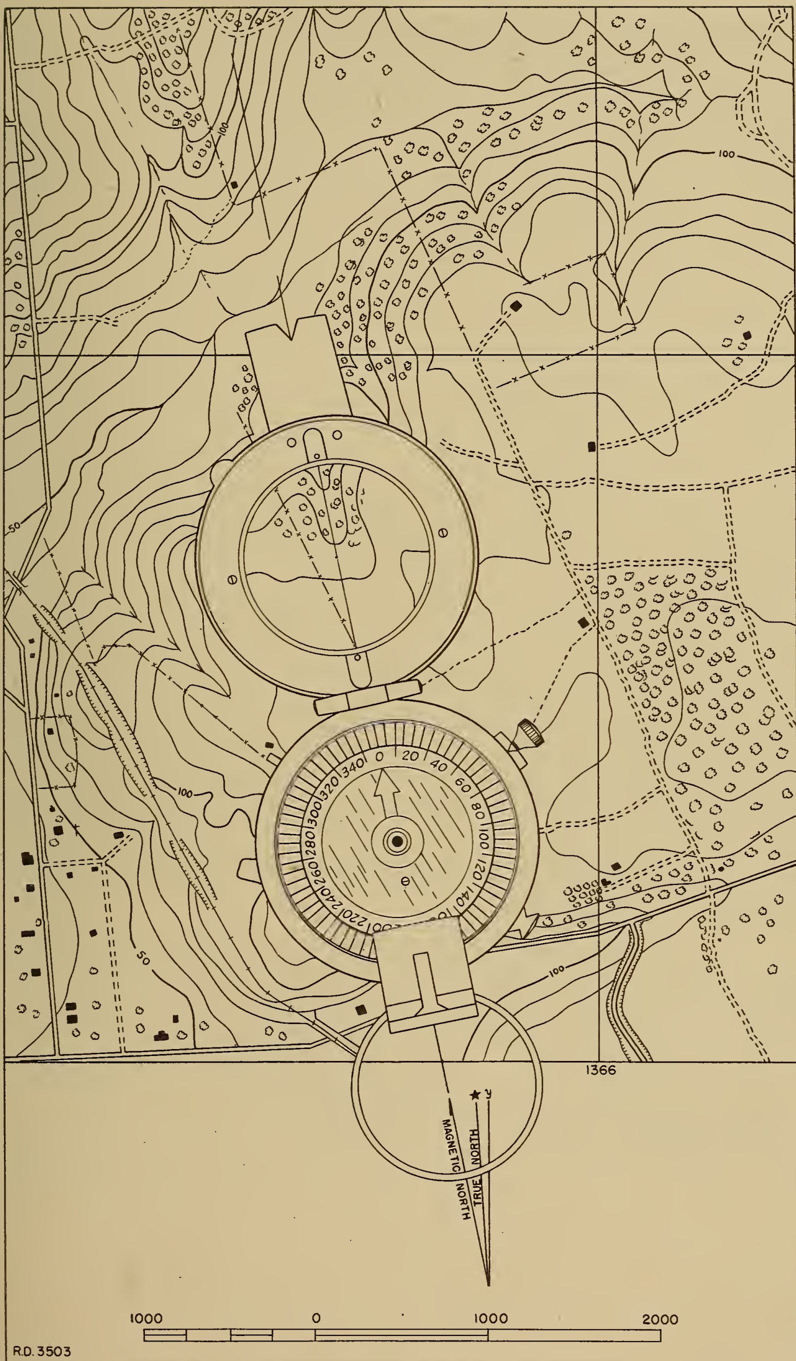


Figure 49.—Orientation of maps by compass.

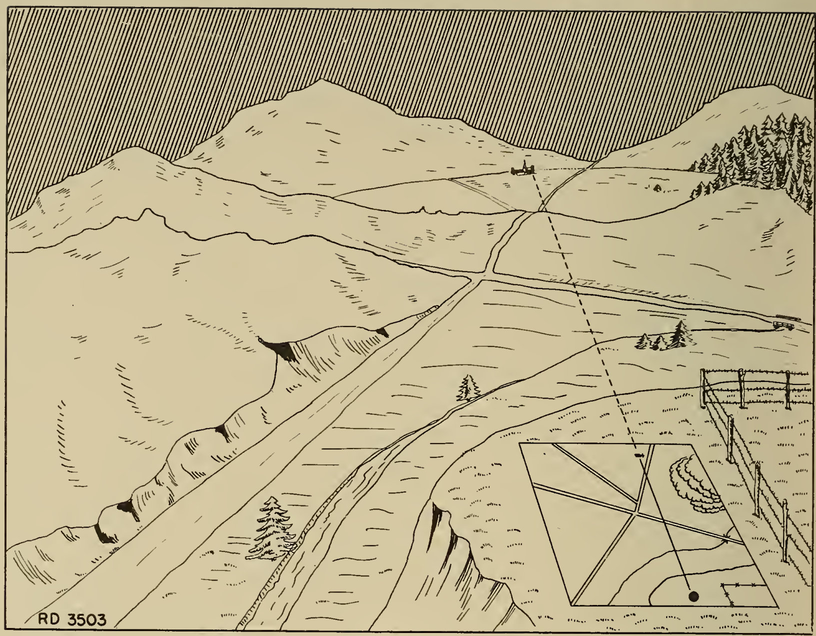


Figure 50.—Orienting map by means of distant point.

68. Finding Observer's Position on Map.—a. Inspection.— If approximate location on a map is known, all the observer has to do is study visible terrain for distinctive features and his position can be found by identifying these features on the map. This procedure is greatly simplified if the map is oriented to the ground. Figure 51 is an example of this method.

b. **Striding or estimation of distance when along road, railroad, etc.**—This method is illustrated in Figure 52. Briefly, the method is to identify on the ground the nearest road bend, road junction, bridge, etc., which appears on the map, such as B in Figure 52. The distance to this point is either estimated or measured by striding and position on the map is obtained by laying off distance AB to scale of map as indicated in the sketch.

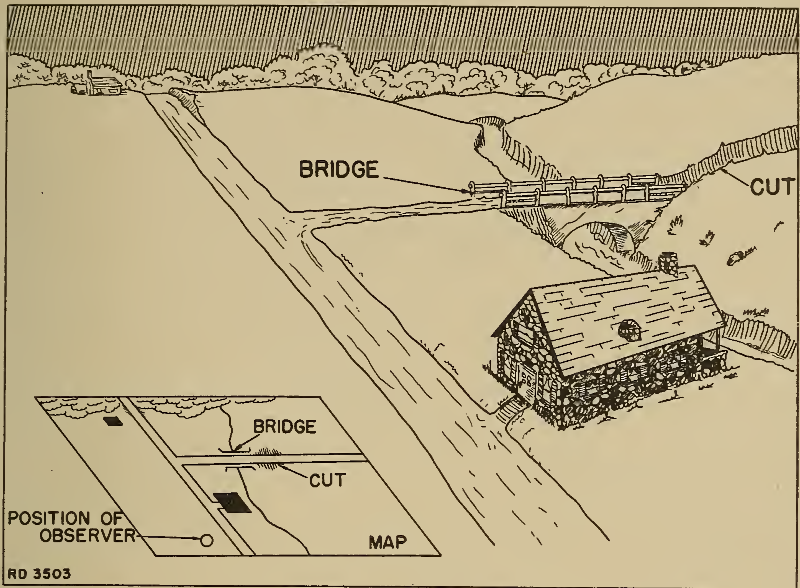


Figure 51.—Locating position on map by inspection.

c. **One Point Resection.—Location of one's position along road or similar feature by sighting on distant point.—** The position may be determined graphically or may be plotted by means of a protractor after a compass has been used to give direction. The first method is the speedier and is most commonly employed when the determination of position is undertaken in the field.

(1) **Graphic method** (Figure 53).—Proceed as follows:

(a) Identify a convenient visible object B on the ground which appears on the map at b.

(b) Rest the map in a horizontal position on some nearby convenient support, such as a fence post, stone, or fold in the terrain, from which B is visible, and set a pin in the map at b.

(c) Orient the map.

(d) Without moving the map, hold a straightedge against the pin at b and aline its edge with the object B on the terrain.

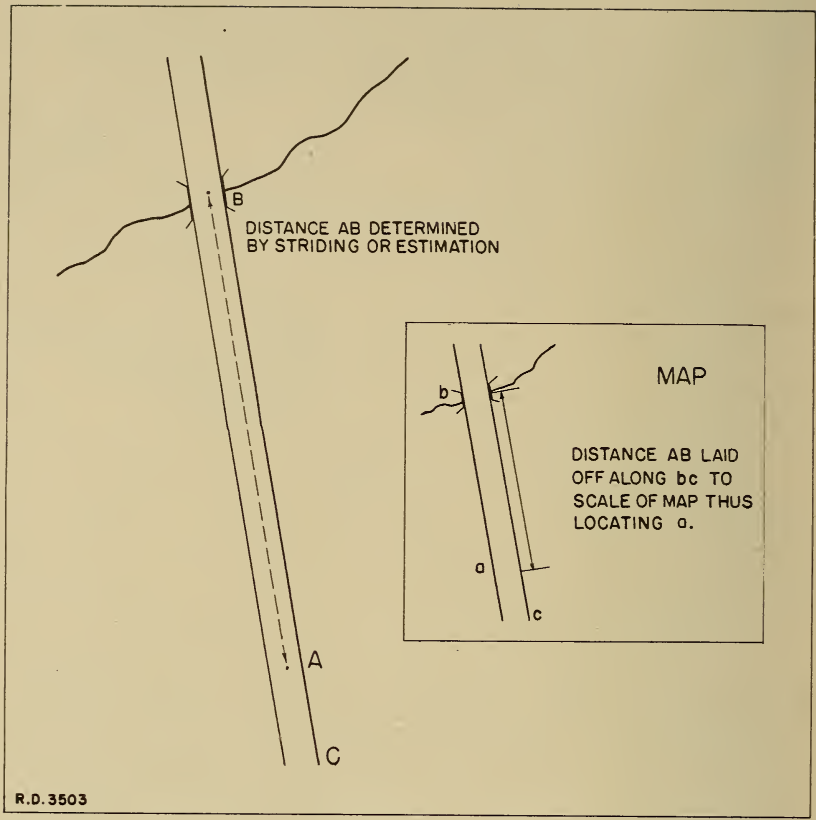


Figure 52.—Location of observers position on map by striding or estimating distance when along road.

(e) Draw a line through b along the straightedge and prolong it to intersection with the road at **a**. This intersection is the point sought.

(2) **By means of compass and protractor** (Figure 54).—Proceed as follows:

(a) Identify a convenient visible object B on the ground whose position **b** appears on the map.

(b) With the compass, sight B and read the magnetic azimuth.

(c) On the map with the protractor lay off this azimuth through **b** and prolong the line until it intersects the road at **a**, which is the position sought.

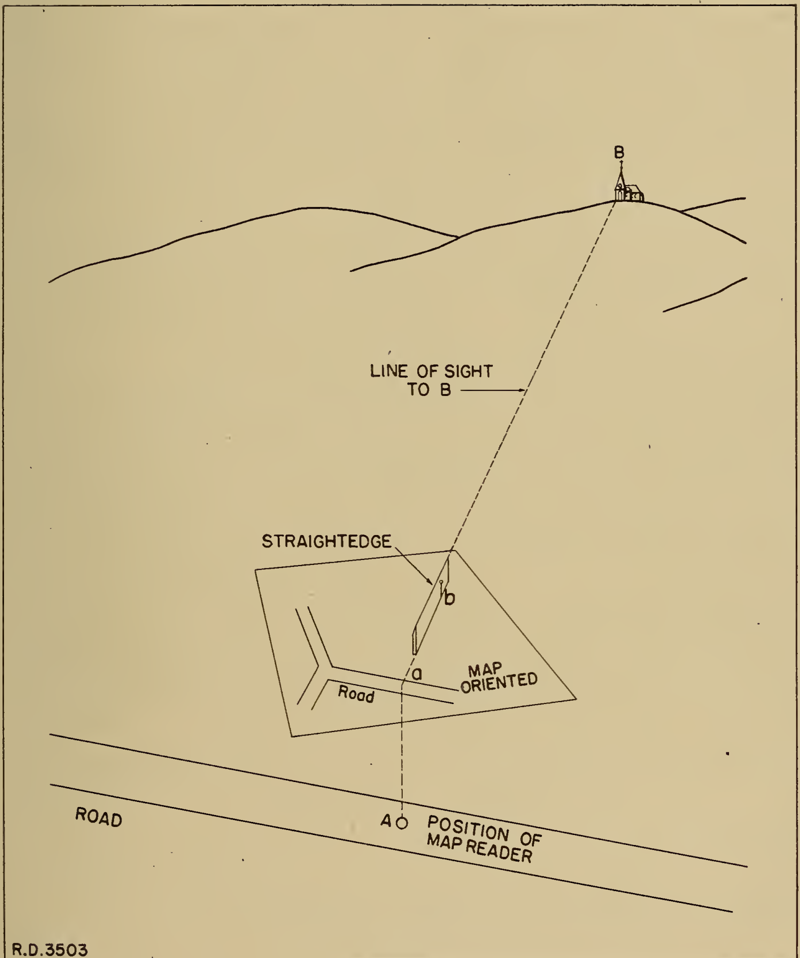


Figure 53.—Location of ones position on map by resection when along road (graphic method).

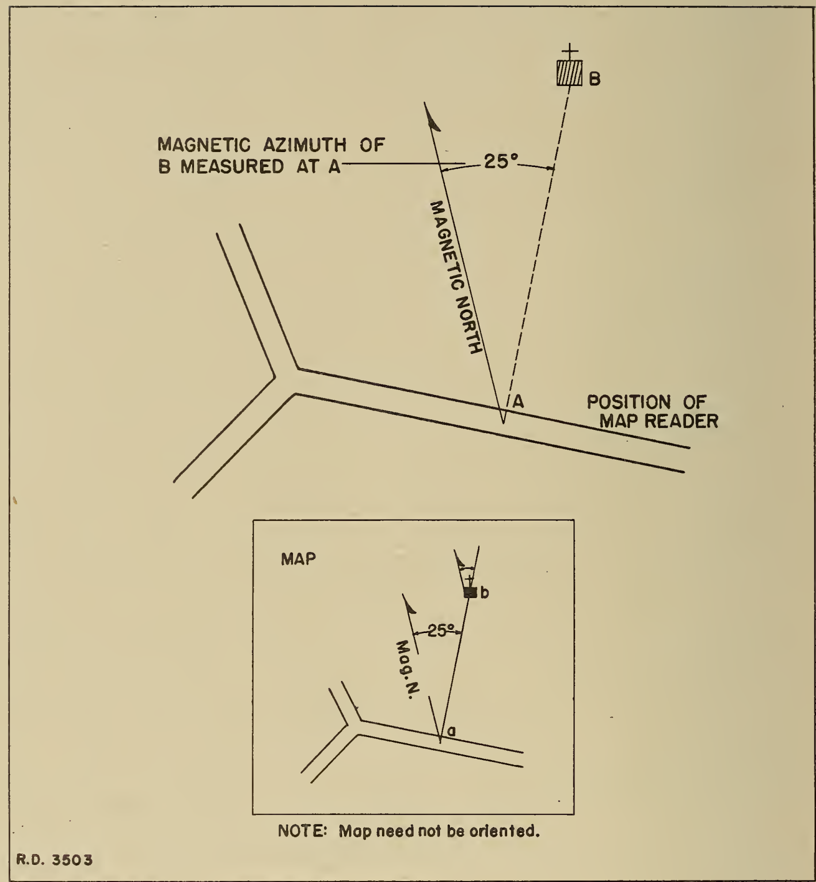


Figure 54.—Location of ones position on map by resection when along road, using compass and protractor.

NOTE: When azimuths are read from observer to a known position, either the azimuth or back azimuth may be used in plotting the direction line through the known position.

d. **Two Point Resection.—Location of one's position by resection from two distant points.**—This method of locating a position is useful when no well-defined feature, such as a road, is in the vicinity. The position may be determined graphically or may be plotted by means of a protractor after directions have been read by a compass. The first method is speedier and is most commonly employed when the determination of position is undertaken in the field.

(1) **Graphic method** (Figure 55).—Proceed as follows:

(a) Select two visible objects on the terrain, as B and C, whose positions **b** and **c** appear on the map, so situated that lines radiating from observer to objects form an angle of 30° to 150° at the observer.

(b) Rest the map in a horizontal position on some nearby convenient support, such as a fence post, stone, or convenient fold in the terrain, from which the objects B and C on the terrain are visible and set pins through their respective map positions, **b** and **c**.

(c) In this position, orient the map.

(d) Without moving the map, sight B and C successively on the terrain along a straightedge held against the pins through the corresponding points **b** and **c**, respectively. Along the straightedge, draw lines through **b** and **c** and prolong these lines to intersection at **a**, which is the point sought.

(2) **By means of compass and protractor** (Figure 56).—Proceed as follows:

(a) Select two visible objects on the terrain, as B and C, the positions of which, **b** and **c**, can be identified on the map and which are so situated that lines radiating from observer to object make an angle of 30° to 150° at the observer.

(b) With the compass sight the objects on the landscape successively, reading the magnetic azimuth to each.

(c) Draw magnetic north guide lines through the map position of each object, **b** and **c**, and with the protractor lay off the respective magnetic azimuths.

(d) Prolong the azimuth lines through the points **b** and **c** until they intersect.

(e) The intersection of these lines at **a** is the map position sought.

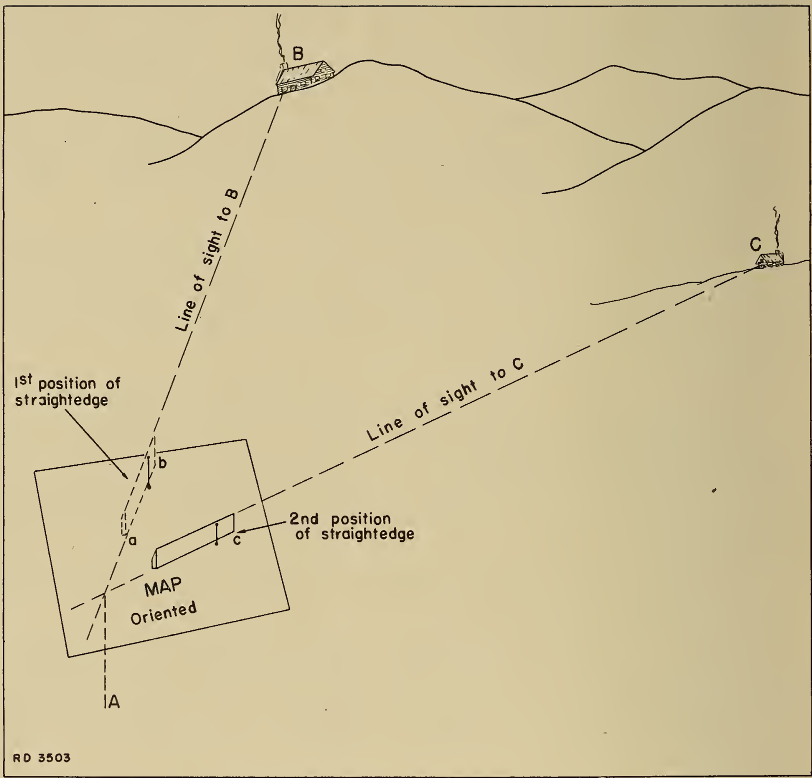


Figure 55.—Location of ones position on map by resection from two distant points (graphic method).

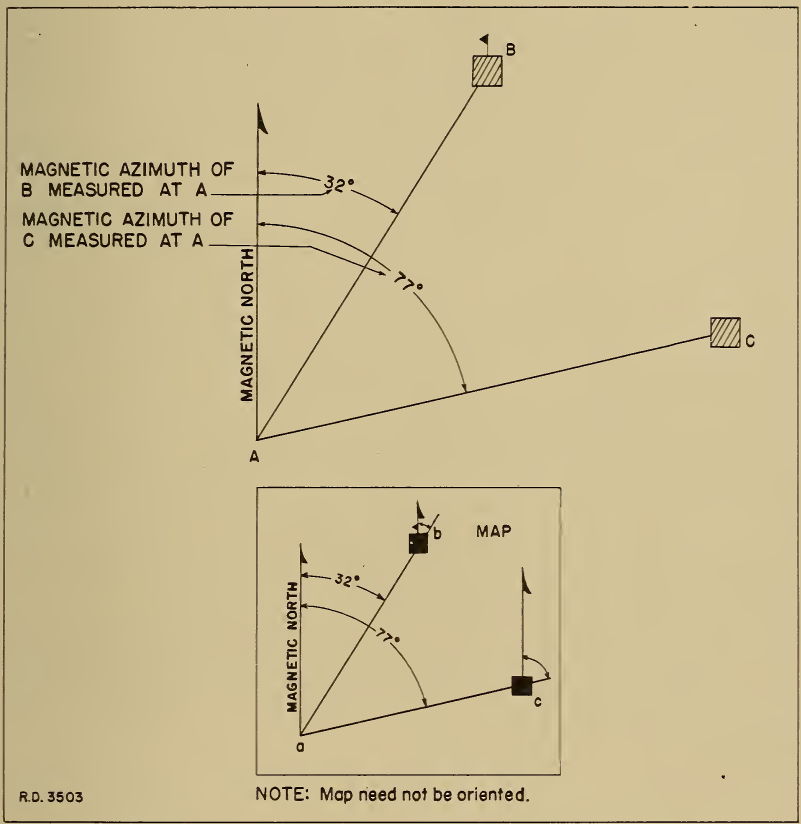


Figure 56.—Location of ones position on map by resection from two distant points, using compass and protractor.

e. **Three Point Resection.—Location of one's position by resection from three distant points (tracing paper method)** (fig. 57).—This method is useful on unoriented maps when the observer is without a compass in indefinite terrain of which only distant prominent features are recognizable or when local attraction due to presence of ore bodies or other material renders the magnetic needle useless.

(1) Select three visible objects on the terrain such as A, B, and C, so distributed that radial lines drawn from observer to each point will yield good angles of intersection (about 30° to 150°) at O, the position occupied by the observer (fig. 57 (1)).

(2) Place a piece of tracing paper on a flat surface, supported on a convenient fence post, rock, or on the ground and set a pin in it at any convenient assumed position of the observer at O.

(3) Place any suitable straightedge against the pin, sight along its edge successively to each object, A, B, and C, on the terrain and draw radial lines along the straightedge toward each object (Figure 57 (2)).

(4) Remove the tracing paper and superimpose it on the map, shifting it about until the three radial lines pass through the conventional signs **a**, **b**, and **c** on the map which correspond to the three objects sighted on the ground (Figure 58).

(5) In this position, prick the map through the original pinhole **o** on the tracing. The point thus located on the map is the position of the map reader.

NOTE: There is only one possible position in which the overlay can be placed so that the three radial lines pass through their respective positions.

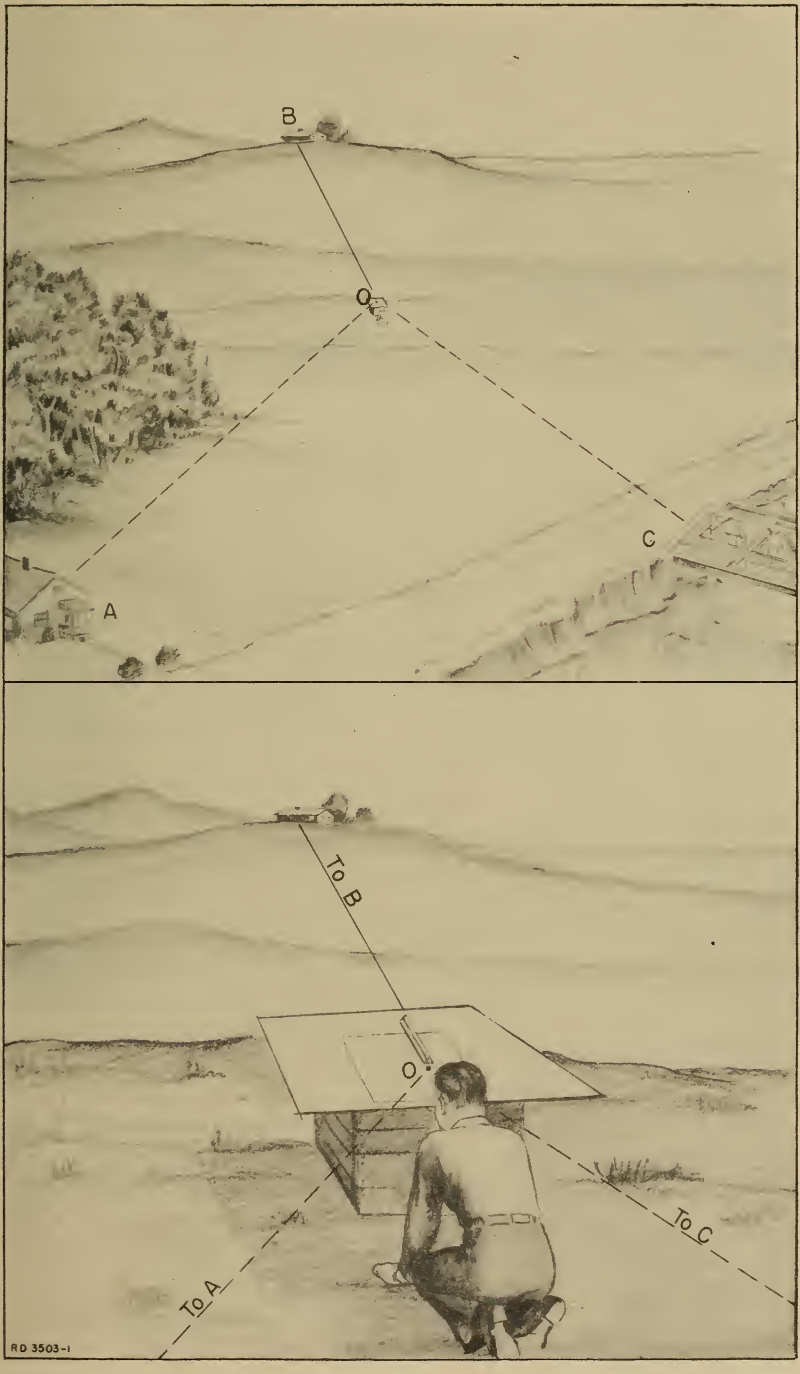


Figure 57.—Three point resection in the field.

Figure 58.—Locating position on a map by tracing paper overlay.

69. Two Point Intersection.—Location of Distant Point by Intersection.—a. **With compass and protractor.**—It is frequently desirable to locate or post on a map distant or inaccessible objects on the terrain which do not appear on the map in hand. This may be conveniently done by intersecting lines from two occupied points of known position on the map. Assume that the location of an object C shown in Figure 59 is desired on a map. In order to locate the position of C, one must occupy successively two positions, such as A and B, from which the object C is visible and read the magnetic azimuth of C from A and B, respectively. By aid of a protractor, these azimuths are plotted through the corresponding positions **a** and **b** on the map. The direction lines prolonged will intersect at **c** on the map, the position sought. Many points may be thus located on the map from two occupied positions.

b. **Graphic method** (Figure 60).—The observer occupies in succession the positions A and B on the ground. In each position he rests the map horizontally on some nearby convenient support and sets a pin in the corresponding map positions **a** and **b**, respectively. In each position the map may be oriented with a compass, by inspection, or by alining the positions **a** and **b** on the map with the corresponding objects A and B on the ground. The last method is the most accurate. At each occupied position a straightedge is placed against the pin in the corresponding position on the oriented map, the object C, the position of which is sought, is sighted along the straightedge and a direction line drawn thereto. This results in two such direction lines, one from each occupied position, the intersection of which gives the map position **c** of the object C. The results may be checked by a direction line from a third position of the observer.

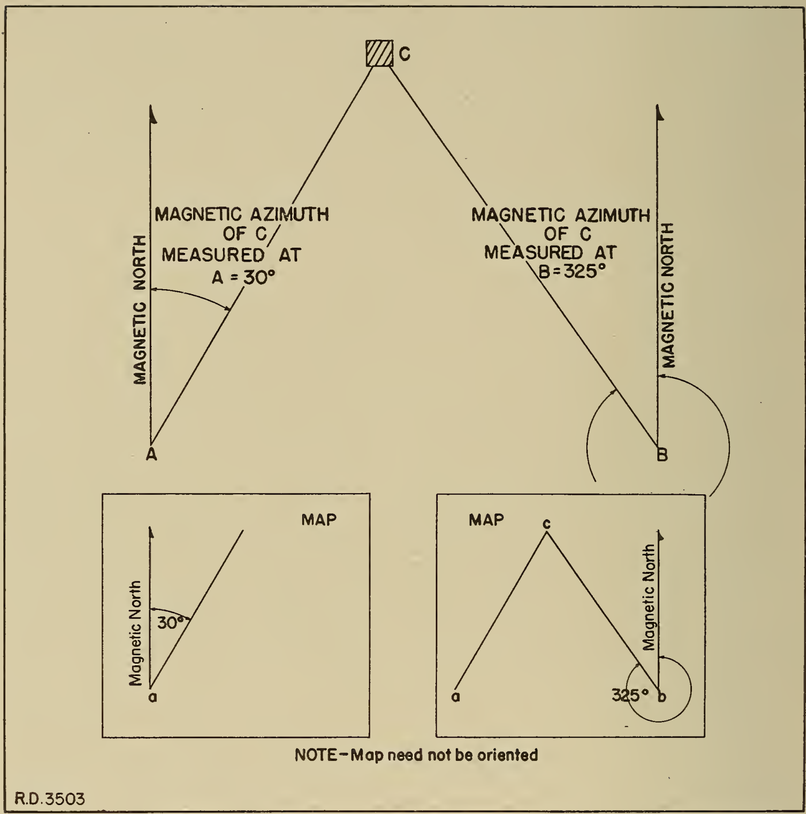


Figure 59.—Location on map of distant point by intersection, using compass and protractor.

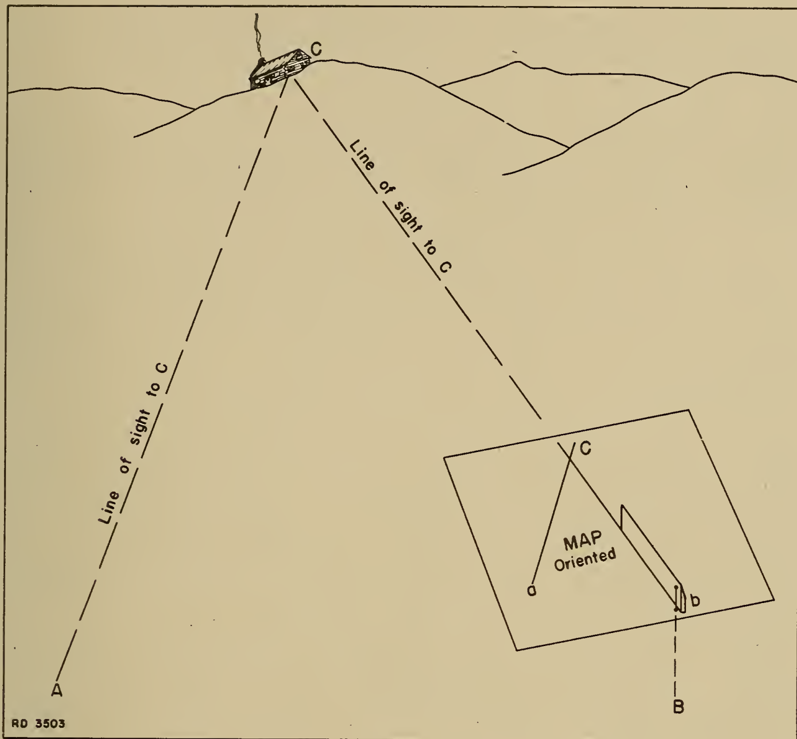


Figure 60.—Location on map of distant point by intersection (graphic method).

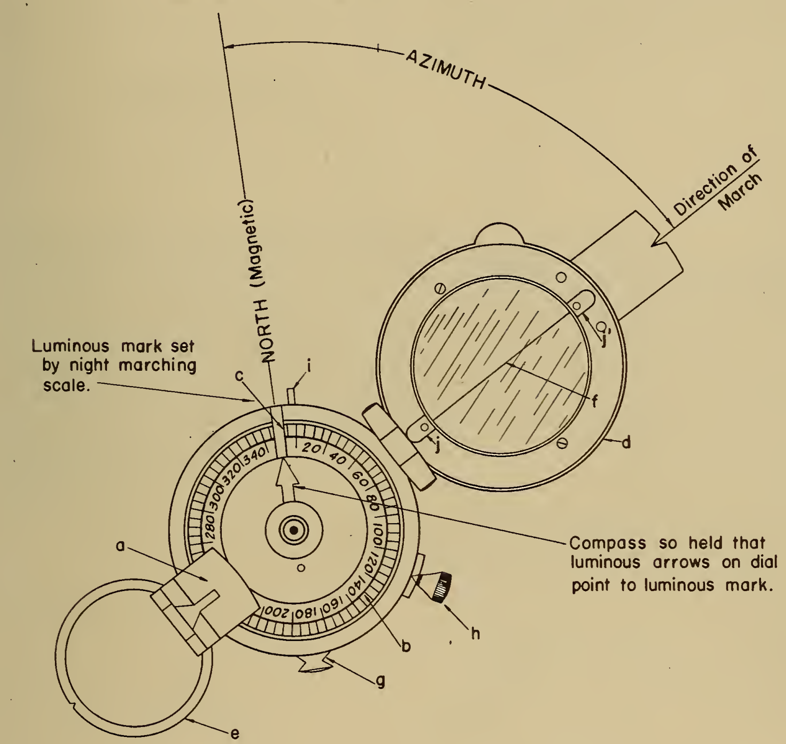
70. **Traverse.**—a. A series of lines of known distance and direction is called a traverse. An approach route to an assembly area, designated with distances and directions from point to point, would form a traverse.

b. In locating on the terrain objects which do not appear on the map and which cannot be intersected, or in exploring unfamiliar terrain equipped with a compass, the method of traversing is useful. This consists of starting from a known point and following observed compass courses from point to point, measuring distances. These course lines and distances when plotted to scale on the map, show graphically the course followed and the map location of any desired point on the traverse. Where the distance to the point sought is great and the intervening terrain is rough, it is not practicable to attempt its location by means of a simple straight course. In such cases the traverse would consist of a meander of many straight course lines and angles making changes of

direction as influenced by the intervening terrain but ultimately terminating at the point sought. Scouts use this method in registering on a map the route they follow.

71. Compass.—a. **Types.**—The three types of compass issued in the service are prismatic, lensatic, and watch. The watch compass is being replaced by the lensatic compass; descriptions of the other two types are given below.

(1) **Prismatic.**—The prismatic compass is shown in Figure 61 showing the more important parts labeled. It consists of a case containing a magnetic dial (b) balanced on a pivot, a hinged cover (d) with a glass window, a holding ring (e) and an eyepiece (a) containing a prism for reading graduations on the dial. The dial has two scales, the outer scale to read through the prism or eyepiece and the inner to be read directly. Both scales are graduated from 0° to 360°. The north point is indicated by an arrow of luminous paint. The glass cover has an etched line (f) which may be used like a front sight, and the eyepiece (a) has a slot that may be used as a rear sight. In case the window in this cover is broken, a horsehair or a fine wire can be threaded through and stretched between the two holes in the cover provided for that purpose. Closing the lid operates a lever (g) which raises the dial to protect the compass from injury when not in use. To lower the dial push clamp (g) forward with the thumb. A second glass protects the face of the dial when the lid is raised. On it is painted a luminous movable index which is used to set angles from the line of sight or north point. This glass can be revolved by unlocking the set screw (h) and turning the corrugated brass ring so that the movable index points at any angle from the line of sight. It can then be set at this angle by tightening the set screw (h). A rubber washer is fixed to the bottom of the case to prevent slipping when laid on smooth objects. The compass is carried in a stout leather case with a belt loop. The outside of the brass case is marked with two scales, one to read azimuths, and the other to read compass directions. Figure 62 shows one use of this outside scale.



a. Eyepiece
b. Compass card or dial (with luminous arrow)
c. Moveable index mark on crystal (luminous)
d. Hinged cover
e. Holding ring
f. Etched front sight cover
g. Clamping knob for compass card
h. Index locking screw
i. Dampening plunger
j-j' Luminous marks on cover

R.D. 3503

Figure 61.—Prismatic compass.

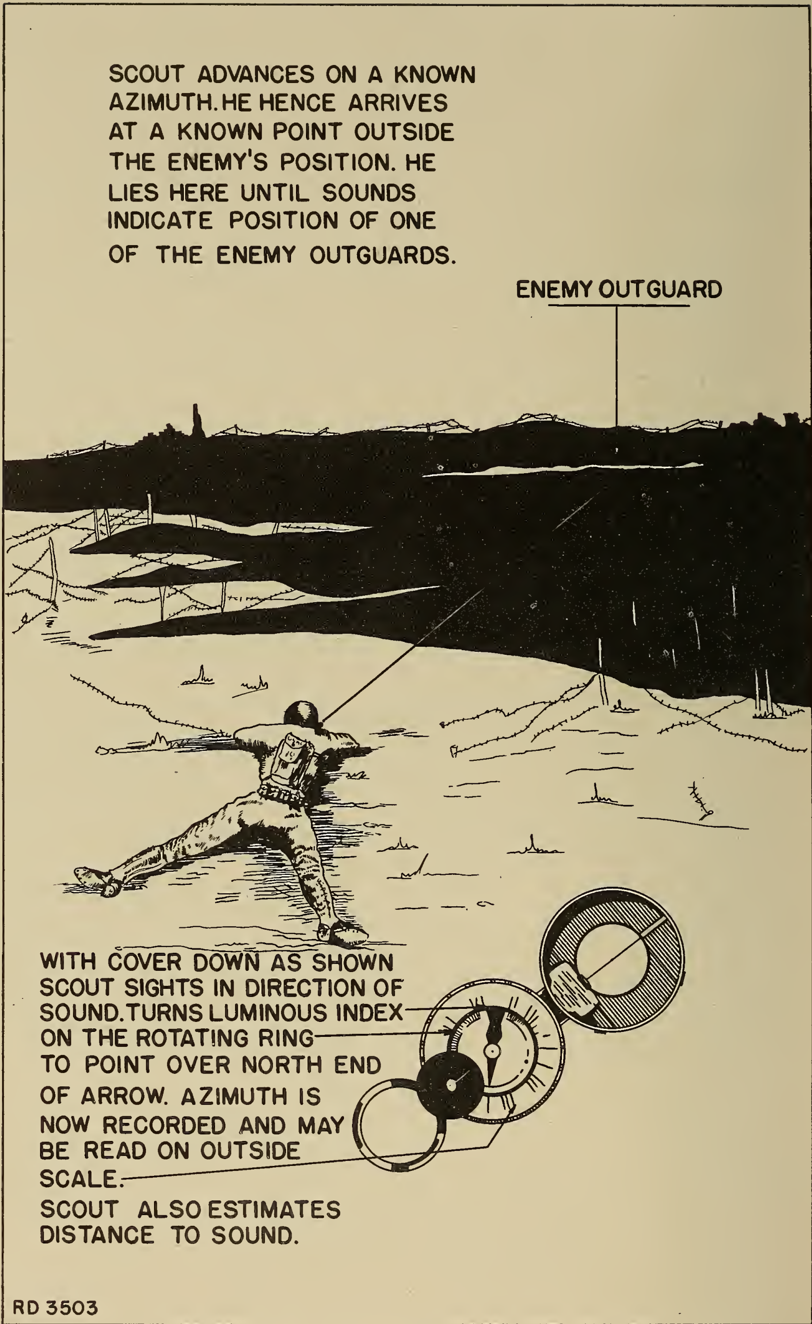


Figure 62.—Use of compass dial.

The compass is affected by presence of iron, steel, or electricity, and will not give accurate readings near an automobile, tank, fieldpiece, machine gun, or power line. A steel helmet, rifle, or pistol on the person of the observer may influence the needle and make readings inaccurate.

(2) **Lensatic.**—The lensatic compass functions in much the same manner as the prismatic compass. The hinged eyepiece is a narrow piece of metal containing a magnifying lens in the larger circular opening. When the eyepiece is tilted so that it is aimed at the forward part of the compass face, the observer is able to see both the scale and a distant point at the same time. It should be noted that the face has two scales, the outer one showing mils, and the inner one showing degrees. The compass is made of light aluminum and is designed so that it may be carried in a pocket.

b. **Measuring azimuth with prismatic compass.**—To read the azimuth to any point proceed as follows (fig. 61):

(1) Raise cover (d) and eyepiece (a) vertically, and lower needle dial at (g).

(2) Hold compass horizontally in front of the eye and pointing in the direction of object, azimuth of which is desired. In doing this utilize every possible means for holding compass and eye steady. Methods used are somewhat similar to those used for sighting a rifle. A good method is to rest head, wrist, and body against a good substantial tree or other nonmetallic object. A prone or sitting position similar to that assumed for firing a rifle is also suitable. The dial may be dampened by operating the plunger (i) with index finger of left hand.

(3) Sighting through slot in eyepiece, line up object with etched line (f) in cover. Hold compass steady until dial comes to rest. Read azimuth indicated on dial as seen through eyepiece. This will be the magnetic azimuth of the line from observer to object.

c. **Marching by compass.**—(1) **Day.**—Often troops are ordered either to march or attack cross country according to given azimuths. Such troops might include patrols or individuals on scouting or messenger missions. Patrol leaders or unit commander may compute from a map azimuths or various legs of their routes to prevent getting lost. Map azimuths must then be converted to magnetic azimuths before they can be used with the compass. Having determined this magnetic azimuth, the leader holds his compass steady and turns it until required azimuth is read on the dial. He then sights along axis of the compass as described in b (3) above and selects a house, tree, rock, or other easily recognizable feature of the landscape in this line of sight. He then marches toward this selected feature until he reaches it or loses sight of it. He then takes another sight as described above and selects a

new feature. This is repeated until he reaches his destination. Note that the compass is used to select successive features on the line of march and is not used when actually marching.

(2) **Night.**—For marching at night, movable index (c) luminous marks (j-j′) on inside of cover, and azimuth scale on the outside of case are used (fig. 61). To march on given azimuth at night, set movable index at desired azimuth, rotate compass until needle points at movable index, and then select some feature on the skyline that is on the axis of the compass. March toward this selected feature. The axis of the compass can be determined by means of the luminous marks (j-j′). Setting the compass must be done in the light, usually by flashlight, screened from observation. On very dark nights where the skyline is not visible, it may be necessary to send one man ahead to the limit of visibility, line him up on desired azimuth, and walk toward him, repeating this as often as is necessary.

SECTION 10

AERIAL PHOTOGRAPHS

72. **General.**—a. **Importance.**—Aerial photographs are used for many different purposes in connection with military operations. In this manual they are considered primarily in conjunction with or as substitutes for topographic maps. The ideal situation is to have an accurate topographical map and a recent aerial photograph of the same area. During the first few days or even weeks in a new theater of operations there is a great possibility that the only up-to-date information of the terrain available would be that obtained from aerial photographs. They would be used in determining distances and directions, and in selecting routes in much the same manner as ordinary topographic maps.

b. **Types.**—(1) Vertical photographs are those made when axis of the camera is kept as nearly vertical as possible.

(2) Oblique photographs are those made when axis of the camera is deliberately tipped from the vertical.

(3) Composite aerial photographs are made with cameras having one principal lens and two or more surrounding and oblique lenses. The several resulting photographs are corrected or transformed in printing so as to permit assembly as verticals with the same scale.

c. **Data on aerial photographs.**—(1) As aids in reading and use, aerial photographs to be used individually will have the following information on the back when issued by the Navy or Marine Corps.

(a) A Bureau of Aeronautics number, as M.A.S.Q 216 (Marine Air Station, Quantico #216)

(b) Date.

(c) Unit—as, (Marine Corps Air Station, Quantico, Va.)

(d) Subject—(plus additional pertinent information)

(1′) Altitude flown.
(2′) Lens focal length.
(3′) Film and filter.
(4′) Type camera.
(5′) Time of flight.

(2) Army Air Corps photos will have information along the black strip at the bottom reading from left to right, as follows:

(a) An arrow one-half inch in length in the lower left hand corner of the negative indicating north, with letter N superimposed over center of shaft.

NOTE: Some photos may show a similar arrow without letter "N" superimposed over the shaft. This is a flight direction arrow, shown in conjunction with the lower left corner neat line, and is not to be confused with a north direction.

(b) Name of locality or nearest locality.

(c) Approximate military grid coordinates of center of photograph.

(d) Scale of photograph expressed as a representative fraction in case of a vertical, altitude above ground in feet and focal length of camera in case of an oblique.

(e) Hour.

(f) Date arranged in the following order: day, in figures; month, in letters; and year, in figures.

(g) Designation of squadron.

(h) Serial number of negative. In addition to a north point, the following is the legend on a vertical:

Saranac, N. Y.—(321-437)—1:20,000—(2:00 P. M.)—(24-Aug-40)—97th-M5. (See fig. 68.)

(3) Mosaics and wide coverage photographs may have in addition to that listed above the following information:

(a) Marginal information similar to that shown on map legends.

(b) Some system of grids, preferably the atlas grid described in paragraph 77.

(c) Names of important features such as town, streams, mountains, highways, etc.

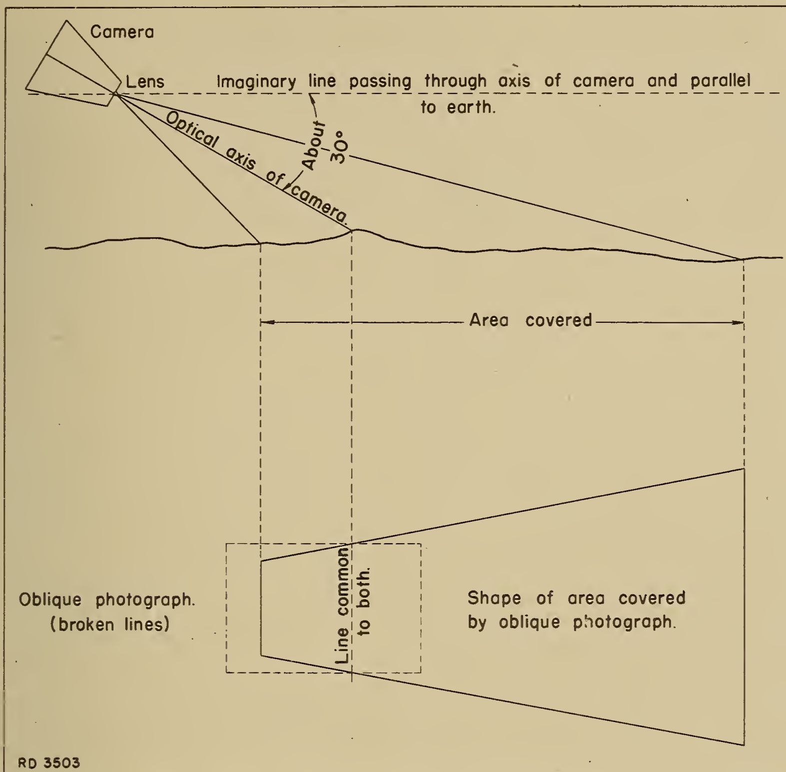


Figure 63.—Relative shape of area covered by oblique photograph compared to photograph itself.

73. **Oblique.**—Normally in making obliques the photographs are taken over the side of the cockpit with the camera intentionally tilted at an angle which will vary according to the mission, but is usually about 30° below the horizontal as shown in figure 63. This procedure gives what is known as a low oblique (fig. 64). Obliques which include the horizon are termed high obliques. Figure 63 also shows the relative shape of the area covered by an oblique photograph as compared to the photograph itself. Note the actual photograph is a rectangular print whereas the area covered by the photograph has the shape of a trapezoid. Distances on oblique photographs cannot be scaled accurately. However, since the oblique picture is taken from a viewpoint similar to that of an observer on a high hill, terrain features have a more normal appearance than they do in a vertical; this characteristic makes them more useful for the study of hills, valleys, buildings, roads, etc. They can also be used to accompany opera-

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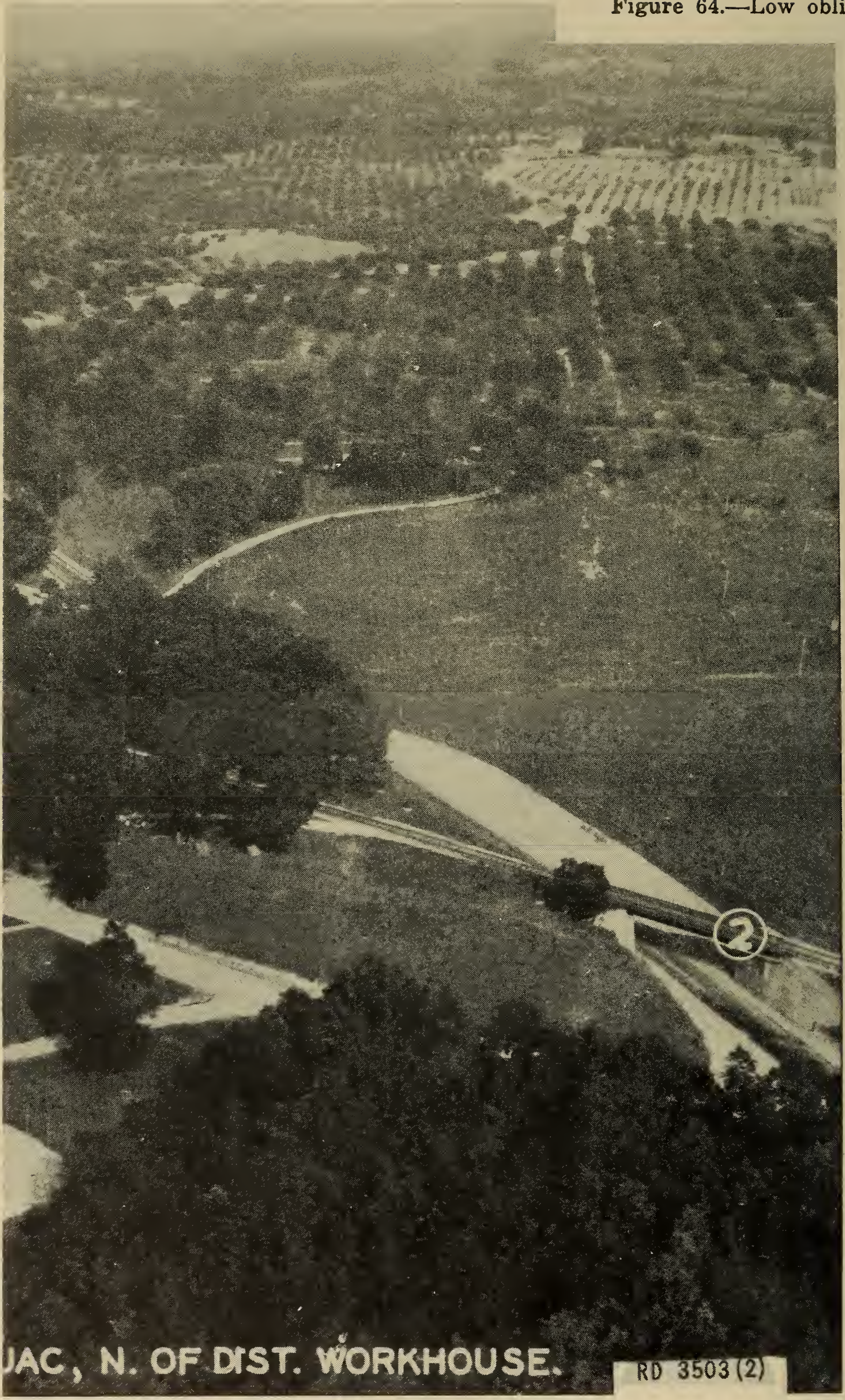
Figure 64.—Low oblique.

Figure 64.—Low oblique.



tions or field orders, to show the line of departure, routes from bivouac to assault position, assembly positions, boundaries between units, objectives, and information of the enemy.

74. Vertical.—Vertical photographs are usually taken through an opening in the floor of the airplane cockpit, with the optical axis of the camera perpendicular to the surface of the earth. Each photograph covers a comparatively small ground area and shows the area somewhat as it would appear on a detailed map or sketch of similar scale. Figure 65 shows a vertical of the area covered by the oblique in figure 64. Note the difference in appearance of objects which appear on both photographs. Note particularly the house at (1), highway underpass at (2), tree and tennis court at (3), field at (4), and orchard at (5). Learning to read a vertical photograph is similar to learning to read a map. It consists in being able to recognize familiar objects on the landscape from their appearance on the photograph, to orient the photograph, to determine its scale, and to determine distance and direction. A photograph, however, is not as easy to read as a map. Important features on a map are emphasized and always are shown in the same manner. On a photograph important features such as roads, railroads, bridges, and streams may appear less important than a great amount of unimportant detail, or may be completely hidden by trees or shadows. Dissimilar objects such as roads, railroads, and canals may look alike, and the same objects may appear to be different on various photographs or even on different parts of the same photograph. Also, a single vertical photograph, unlike a topographic map, contains no definite information of ground forms and elevations. Hills, ridges, and depressions are difficult to visualize unless an analysis of the drainage system within the area is made. Even when this is done relative elevations are not apparent on the photograph. On the other hand, an aerial photograph is very valuable for the reasons that it—

a. Possesses in pictorial form a wealth of detail which no map can equal.

b. Can be prepared for use in a short time, much quicker than making a new map.

c. Is up to date.

d. Can be made of any area, even those inaccessible to ground mapping parties.

75. **Identifying Terrain Features.**—a. Identifying features of terrain on photographs requires a certain amount of practice which is best gained by actually comparing the photograph with the ground. When this is not possible, the next best method is to compare photographs with a good map of the

same area. Actual identification of objects on an aerial photograph or on a mosaic is effected through one or more of the following means:

(1) Shape of object.

(2) Its tone, or relative colors from white through various shades of grey to black.

(3) Shadow it casts.

(4) Apparent or relative size.

(5) Relative location or environment.

b. In identifying features on a vertical photograph, always hold the picture so the shadows are falling toward you. Figure 66 shows several ground features numbered to correspond to the numbers of the subparagraphs below containing their description; when reading the description, look at Figure 66 and note how reasons given for each identification apply.

(1) Plowed field looks light in the photograph because it reflects a relatively large amount of light.

(2) Meadow looks darker largely due to the shadows of the grass. The meadow is said to have more texture than the field. The difference between the meadow and the field is similar to the difference between satin and plush velvet. Although both are the same color, the plush looks darker due to the shadows of the hairs which stand erect, but it can be made to look lighter when smoothed down.

(3) In this photograph, the highway bridge looks lighter than the water. It can be identified by its size, shape and its shadow on the stream.

(4) Building can be identified by its size, shape, difference in appearance of the two roof slopes, and by its shadow. The shadow looks darker than the building.

(5) Woods appear relatively dark because of deep shadows of the trees. They have much texture and reflect little light.

(6) A stream can be identified by its meandering course. Even through open fields some trees or bushes usually grow along its banks. In a dense wood it will appear as a thinning out of the surrounding growth. The water looks very light or dark, depending upon the relative positions of sun, camera, and water.


5
6
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Figure 65.—Vertical photograph.

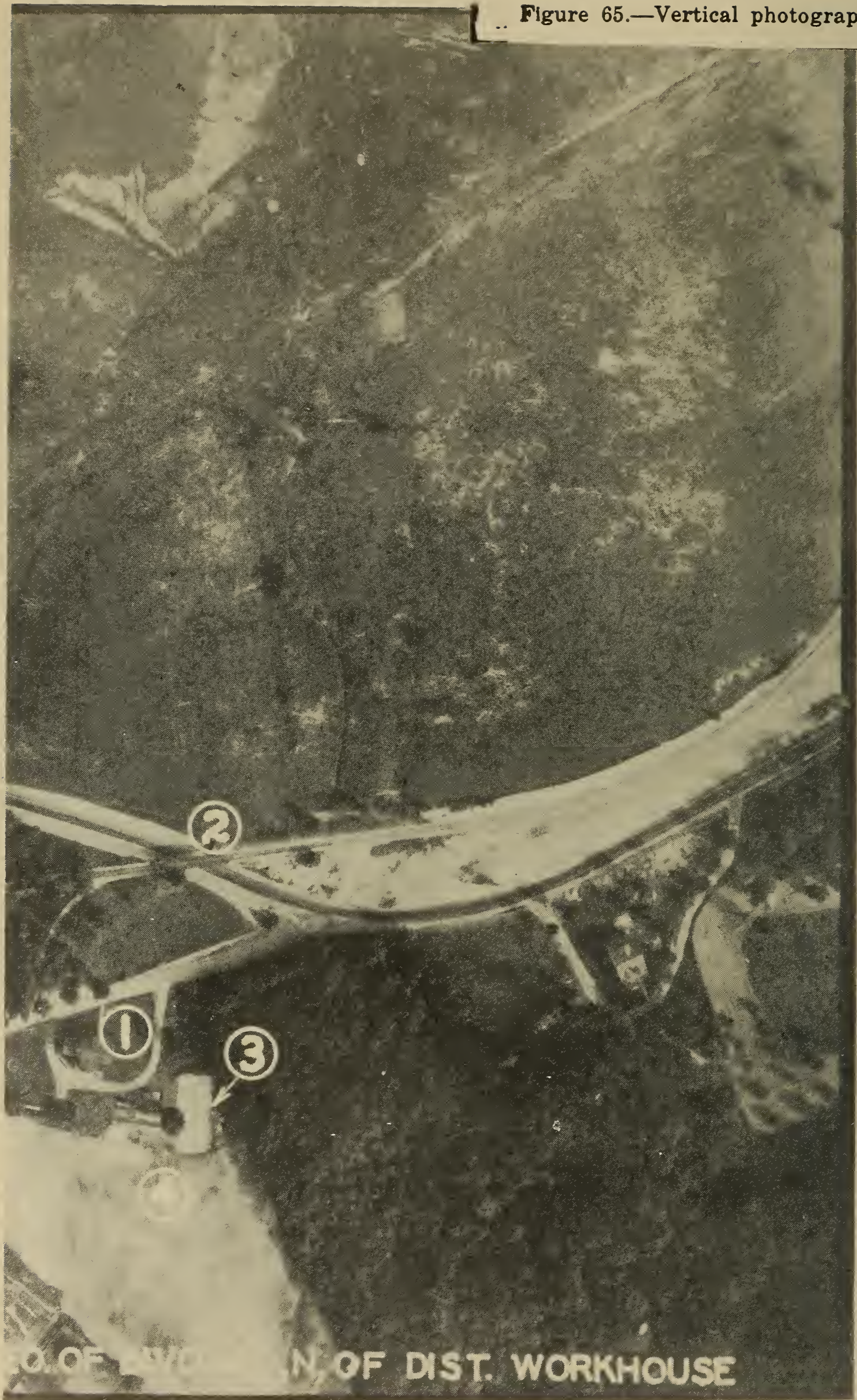

Figure 65.—Vertical photograph.

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Figure 66.—Identifying Terrain Features.

Figure 66.—Identifying Terrain Features.

(7) Fence lines are identified by difference in texture between fields they separate and usually look dark in the photograph because of shadows of bushes growing along them.

(8) Roads are identified by their straight lines, uniform width and the fact that their surfaces are usually smooth and reflect much light. (Modern open asphalt texture surfaces will appear darker than other road surfaces.)

(9) Trails are also light but are more variable and narrow in width and more crooked than roads.

(10) Railroads have more gradual curves, generally have more fills and cuts, and are straighter, and darker in appearance than most roads.

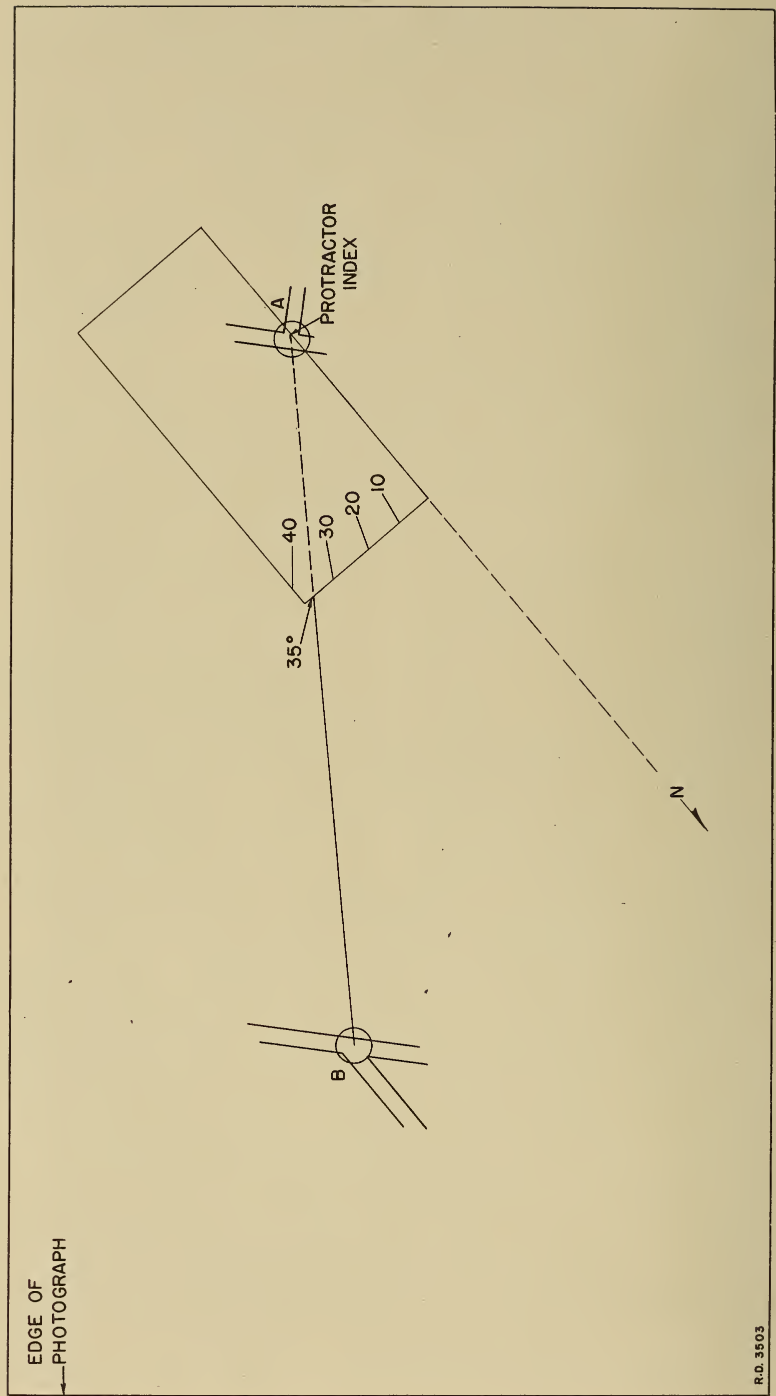
(11) Orchard is identified by its shape and by the straight and regular rows of trees. Shadows of equal length show the trees are all about the same height.

(12) Mud flats along the stream look darker than the water and have lighter spots in them due to pools of water.

(13) Cluster of buildings shows this a village.

c. A careful study of Figure 66 combined with a study of Figures 64 and 65 should make the student reasonably proficient in interpreting aerial photographs. It should be remembered that the pictorial effect of vertical aerial photographs is influenced by shadow. In order that this effect will aid rather than hinder the student, he should place the photograph on a table between himself and a lamp, window, or other source of light, shifting it to avoid the glare from its surface and so that shadows on the photograph fall toward him. In this position objects will have their normal appearance. If the photograph is reversed, that is, placed so that the shadows fall away from the student, actual hollows may appear as hills and trees as holes in the ground.

76. Orientation.—a. **With map.**—(1) When the photograph is used in conjunction with a map it should be oriented with a map. Maps are printed with the north of the map at the top and all lettering, grids, etc., are added on that basis. However, no attempt is made to take photographs to fit this scheme. Photographs may be received without any lettering or direction for orientation. Consequently it may be necessary to study the photograph and identify objects to use in orienting it. When objects shown on the map are found on the photograph it is a simple matter to orient the photograph with respect to the map. Road systems and streams are useful for this purpose. A magnetic north line should then be drawn on the photograph parallel to that on the map.



Figue 67.—Placing magnetic north line on aerial photograph.

(2) Another method of drawing the magnetic north line on a photograph is to select two points on the photo that can also be easily identified on the map. The points should be fairly far apart, and line joining them should pass close to the center of the photograph (points A and B, fig. 66). Measure on map azimuth of line joining these points. Convert this azimuth to magnetic azimuth. Assume the magnetic azimuth of AB on the map to be 35°. Lay protractor on the photograph (fig. 67 with center of protractor at A and line AB cutting the 35° reading. The base line of the protractor is now lying on magnetic north and south line with north toward the 0° reading. A line with N arrow is drawn parallel to this where desired on the photograph.

b. **With ground.**—A photograph may be oriented with the ground by placing some well-defined line as a road on the photograph parallel with the same line visible on the ground. This is similar to the orientation of the map described in paragraph 67. The same method is used in locating observer's position on a photograph as is used on a map.

c. **By shadow.**—There may be times when an observer in the field finds it impossible to orient a vertical aerial photograph by either of the above two methods. A third method of rough orientation by use of shadows can be used. In the northern hemisphere shadows fall to the northwest in the morning and to the northeast in the afternoon. Assume the photograph is taken between the usual hours for aerial photography, that is, 10:00 A. M. to 2:00 P. M. The photograph is laid on the ground with the shadows pointing slightly west of north if the photograph was taken in the morning or slightly east of north if taken in the afternoon. The photograph is then approximately oriented. If the exposure is before 10:00 a.m. or after 2:00 p.m., the photograph must be turned west or east of north a correspondingly greater distance.

77. **Atlas Grid.**—a. Because of variations in scale, other inaccuracies, and difficulty of locating grid lines, the military grid is not used on photographs or uncontrolled photomaps. The atlas grid is used instead with grid lines always 1.8 inches apart regardless of the scale. With this interval, on a 1:20,000 photograph the grid lines are about 1,000 yards apart. The lines are numbered from the bottom up, and lettered from left to right. Starting at the left edge, the first line is A, the second B, etc. Therefore, the origin of coordinates at the lower left-hand corner of the photograph is (A.0-1.0) (fig. 68). Points can be located accurately by decimals of the grid interval.

b. In the process of reproduction, the edge of a photograph may vary and successive prints may differ. For the purpose of making accurate measurements, the neat lines,

which are of constant dimensions are considered as the edges of the photograph. Only the corner ticks of the neat lines are usually registered on a photograph. Its ticks at the lower left corner are used as the origin for the Atlas grid. The coordinates of point P (fig. 68) would be written (C.5-4.2).

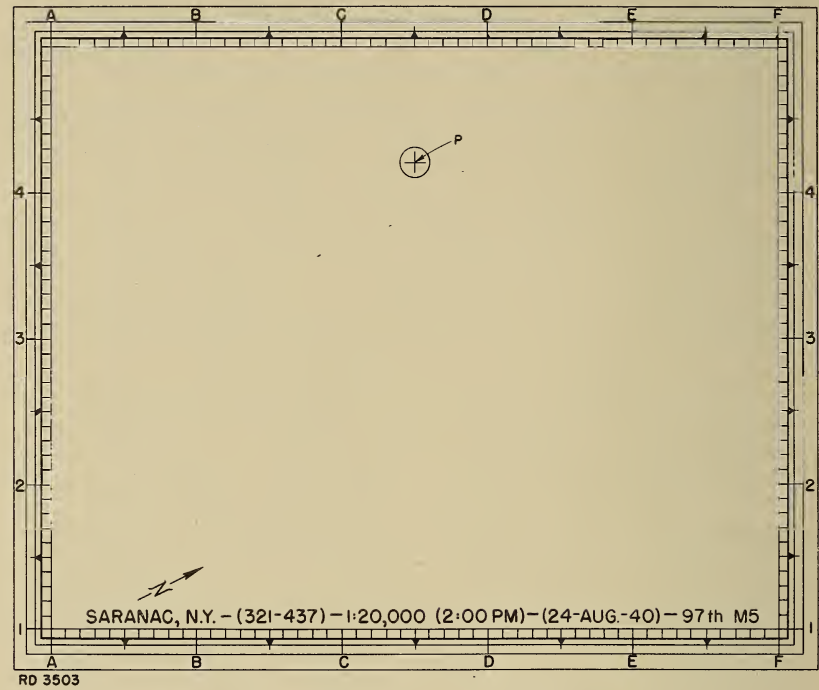


Figure 68.—Atlas grid and marginal data.

c. Various other special grids may be used on aerial photographs or maps. They are generally devised and named for a single operation and generally are based on the atlas grid. A knowledge of the atlas grid will give a background to interpret other grid systems.

78. **Scale.**—Customarily photographs intended to be used as substitutes for maps will be marked as described in paragraph 72. However, they may be received without complete information, as for example, with the scale omitted. In this case the scale must be determined by some other method.

a. **By focal length and altitude.**—Generally the focal length and altitude at exposure will be shown. This information would appear in the marginal data as follows: (12″-20,000). This means that the picture was taken with a camera focal length of which was 12 inches and was 20,000 feet above the ground at time of exposure. By inspection of figure 69 it may

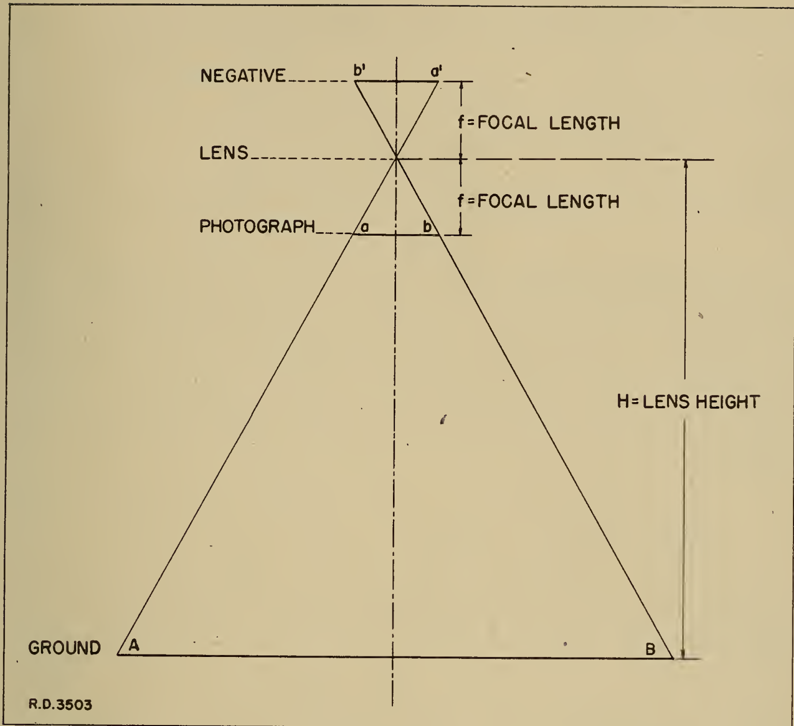


Figure 69.—Diagram showing relation of scale, focal length, and lens height.

be seen that there is a direct relation between the focal length of the camera, height of the plane, ground distance AB and corresponding distance ab on the photograph or

$$\frac{f}{H} = \frac{ab}{AB} = RF$$

If the focal length is 1 foot (12 inches) and the altitude of the plane is 20,000 feet then the scale of the photograph will be $\frac{1}{20,000}$ or RF = 1:20,000.

If the focal length had been 6 inches, then the scale would have been $\frac{6/12}{20,000}$ or $\frac{1/2}{20,000} = \frac{1}{40,000}$ or RF = 1:40,000.

Hence the general expression or formula is:

$$RF = \frac{\text{Focal length in feet}}{\text{Height of plane in feet}}$$

In some cases the altitude is the elevation above sea level, and not the elevation above the ground. If the average ground elevation is much above sea level, allowance must be made for this by reducing the plane's height by the elevation of the ground. For instance, in the example given just above, if the ground had been 2,000 feet and the altitude given had been the elevation above sea level, the RF would have been actually

$$\frac{1/2}{20,000\text{-}2,000} = \frac{1}{36,000} \text{ or } 1:36,000 \text{ instead of } 1:40,000.$$

b. **By comparison with map or ground distance.**—The average scale of the photograph may be computed by comparison of the distance between two points on the photograph with corresponding distance between the same points on the ground or on a map. For best results the points chosen should be located on the photograph so that straight lines joining them pass fairly near to the center and well across the face of the photograph. If required to find the scale of the photograph in Figure 66 by comparison with a 1:20,000 map of that area, select two point such as A and B, that are easily recognizable both on the photograph and on the map. Measure the distance between them both on the photograph and on the map. In this case assume the map distance to be 2 inches, which on the ground would be 2 $\times$ 20,000 = 40,000 inches, since the scale of the map is 1:20,000. The distance between points A and B on the photograph is 3.8 inches. Since it is known that the distance on the ground is 40,000 inches then the RF of the photo is

$$\frac{3.8}{40,000} = \frac{1}{10,526} \text{ or } 1:10,526.$$

Now suppose it is required to find the scale of the photograph in Figure 65 by comparison with a 1:10,000 map. Select two points such as (2) and (6) that can be identified easily both on the photograph and on the map. Proceed as above and in this case assume map distance to be .8 inches which

would be $8 \times 10{,}000 = 8{,}000$ inches on the ground. The distance on the photograph is 3.5 inches. Therefore the RF of the photograph would be

$$\frac{3.5}{8{,}000} = \frac{1}{2{,}286} \text{ or } 1{:}2{,}286.$$

Note that in both examples, points were selected so that lines connecting them passed close to the center of the picture and that the points were far apart.

79. **Mosaic.**—A mosaic consists of several overlapping vertical photographs joined together. When these photographs are oriented with respect to each other by matching detail in the overlap or along the border, the result is an uncontrolled mosaic which gives a good pictorial effect of the ground but may contain considerable errors in scale and direction. When the several photographs are oriented by means of points along the line of flight and adjusted on previously selected ground points, the result is a controlled mosaic. The controlled mosaic is more accurate and for many purposes is as useful as a map. When several photographs taken from a single airplane flight are joined, the result is a strip mosaic. Strip mosaics are commonly used in the early stages of combat as they are quickly made and give a fairly accurate representation of a more or less extended but narrow section of the terrain.

80. **Photomaps.**—A photomap is a single photograph, composite, or mosaic which has been prepared by the addition of grid, marginal and place-name data, and produced in quantity by contact printing or lithography. When time for preparation and available information permit, this data will be in the same form and as complete as for standard maps. Since the photomap, however, finds its greatest use in providing information quickly, quite frequently much of the data usually found on a map will be missing.

81. **Marginal Data.**—Marginal data for the reproduced individual photograph will be that given in paragraph 72c. Photomaps which are made from mosaics and certain wide coverage photographs may have, in addition, the following information:

a. Marginal information similar to that shown on maps, such as the graphic scale of yards.

b. Some system of grids, usually the atlas grid.

c. Names of towns, streams, mountains, highways, and other important features.

82. **Care in Use of Photomaps.**—Photomap users will make their own estimates of the reliability of the information portrayed by examination of the marginal information and by consideration of the basic materials used in their prepara-

tion. The date of the aerial photography gives an indication of the probable accuracy of portrayal of cultural features as they now exist. If the photomap is a simple reproduction of a single photograph or composite, it will be understood that the indicated scale is approximate and that over-all scale errors due to tilt and relief displacements will exist. Photomaps from mosaics will be indicated as "controlled" or "uncontrolled." Photomaps made from uncontrolled mosaics are important primarily because of their pictorial value, and should not be considered as accurate for the determination of distances and directions. If the area is relatively flat and the photographs have been taken at fairly constant elevation with little tilt, even the uncontrolled mosaic will approach the dimensional and directional accuracy of the best maps. A photomap from a controlled mosaic may be accepted as reasonably accurate for measurement of distances and directions, despite the fact that image displacements at the junctions of the individual prints will be apparent. Such photomaps may be accepted with the same degree of confidence as a first class planimetric map of the same scale.

83. **Aids in Use of Photomaps.**—Photomaps reproduced in quantity by photolithography lose some of the clarity, sharpness, and contrast of the original copy. Even in poor reproductions, however, the principal features of the terrain can be discerned by careful study and through the application of general knowledge of terrain characteristics. It will assist the map reader considerably to trace the drainage system, accentuating the stream lines with a sharp blue pencil, avoiding, at the same time, the obliteration of essential details. In the same time, the permanent ridge lines may be traced in brown lines, thus enabling the map reader to grasp at a glance the major features of the terrain.

84. **Methods of Reproduction.**—Photomaps are reproduced in quantity by contact printing, by continuous tone lithography, or by halftone lithography. The contact process produces the best results, but is much more expensive and time consuming than lithography. Furthermore, rapid contact printing of large size photomaps requires equipment which is too bulky for field use. In the continuous tone lithographic process, much of the contrast of tone which appears in the original photograph or mosaic is lost. As a result, many small features become merged into the background and are difficult or impossible to discern. When the original photography has been satisfactory, the best results in quantity reproduction are obtained by halftone photolithography. Reading glass examination of a photomap reproduced by this process will disclose the individual images are made up of a series of dots, the darker the object, the denser the dots. Most of the original tone contrast of the photograph is retained. However, in the halftone process also, some details

of the landscape such as individual bushes, small houses etc., may be too small to create a sufficiently distinct dot pattern to render them recognizable. Another feature to be observed in the study of photomaps from mosaics is the variation in tone and contrast between adjacent photographs used in the preparation of the mosaic. Because of changes in exposure conditions, as well as variations in printing of individual photographs, marked differences in the tone of adjacent sections of the mosaic frequently occur. Such differences in tone should be recognized readily and should not be misinterpreted as actual changes in landscape texture.

85. **Stereovision.**—a. **General.**—The ordinary photograph, has a flat appearance, which makes it difficult to distinguish between hills and valleys. If two overlapping photographs, known as a stereopair, are viewed either with the naked eyes or with some type of stereoscopic instrument, the effect of depth or relief will be seen and ability had to recognize the actual ground forms. This type of study gives valuable training in understanding and reading both single vertical photographs and photomaps. Consequently all military personnel should learn and practice stereovision. There are several methods that will assist in acquiring this ability and each individual should experiment until he finds the method that gives him the best results. This ability comes very quickly to most; others will have to use patience and perseverence to obtain it. Experience with large groups of men reveals that anyone with good enough eyes to be in military service can acquire the ability to see stereoscopically. Stereo studies properly done put no strain on the eyes, and some oculists even prescribe similar exercises to strengthen the eyes. However, when magnifying spectacles are used, they should be removed from the eyes before looking up from the photographs.

b. **Anaglyph.**—Beginners in stereo studies often have difficulty in getting the effect of relief by means of aerial photographs. A simple method of illustrating stereovision is by means of the anaglyph. The anaglyph consists of two different photographs of the same area printed on the same sheet but slightly offset. One is printed in red and the other in blue or green. Relief can be seen when the anaglyph is viewed through a pair of colored spectacles. If the spectacles are reversed or the print is turned upside down, the relief is reversed and ridges will appear as valleys and valleys as ridges. The anaglyph has no practical military value and is used as a quick aid to beginners to illustrate the effects to be obtained by practice in stereovision.

SECTION 11

HYDROGRAPHIC CHARTS

86. **Definition.**—The hydrographic chart is a conventional representation of a portion of the earth's surface, chiefly of that portion which is covered by water, or that on which land and water meet to form the shore line. In the conduct of landings, Marine Corps personnel will be concerned with the latter class only.

87. **Sources From Which Charts Are Obtained.**—There are three sources from which charts may be obtained in the United States: the Coast and Geodetic Survey of the Department of Commerce, which publishes, from its surveys of the coast line, charts suited to the purpose of navigation and defense; the Hydrographic Office of the Navy Department, which has charge of the duplication of charts issued by foreign governments and the preparation and publication of charts of coasts not under the jurisdiction of the United States; and the Corps of Engineers, U.S. Army which prepares and issues charts of the Great Lakes.

88. **Types.**—a. Generally speaking, there are four classes of charts, each made to its own particular scale, and intended for use in its own peculiar way.

(1) The first, known as the **sailing chart,** embraces long stretches of coast line or large reaches of water. This class is of interest to navigators of overseas craft only.

(2) The second, known as **general charts of the coast,** are made to a scale three times as great as the first class, and the charts themselves show limited, but still large areas, such as the Gulf of Maine, the Puget Sound Area, Chesapeake Bay, etc. They are intended for coastwise navigation, chiefly by the use of landmarks, buoys or soundings, and are of little use in landing operations, but may be employed when more detailed charts are not available.

(3) The third class, known as **coast charts,** are constructed on a normal scale of one inch to the nautical mile, or one inch to one and one-seventh land miles, which is about five times the scale of the second class. This class shows the details necessary for close coastwise navigation, for entering bays and harbors, and for navigating inland waterways.

(4) The fourth class embraces **harbor charts,** which are constructed on large scales, intended to meet the needs of local navigation. No definite scale is prescribed, as the scale used in each case must be adequate to afford an accurate and useful representation of the waters and coast line to be encountered. However, it has been found that, as a general rule, scales varying from 1:40,000 to 1:20,000 are to be found on the charts.

b. The last two classes of charts are most suited to the needs of Marine Corps personnel in landing operations, as they show in sufficient detail the aids to navigation, bottom, channel, and shore line conditions to enable subordinate commanders to pick up suitable routes to the beach as well as to pursue their operations for at least one thousand yards inland. Charts of these two classes will form the basis for study.

c. While the scales given above are standard for charts of the coast line of the United States and possessions, these scales may not apply to foreign charts or copies thereof. However, in all cases, as in the case of topographic maps, a scale of some sort is usually to be found on the chart, which scale should be verified as soon as possible by the prospective user.

89. **Correction.**—The prospective user should also examine the chart with a view to ascertaining the date of its manufacture or issue. In many instances, especially in the case of river mouths or harbor entrances, there is likely to be a change of a drastic nature in the condition of bottom, channel, or shore line, and a chart of some age, which has not been corrected up to date, is likely to prove more dangerous than no chart at all. The date of manufacture and/or of issue is usually printed or stamped prominently on the face of the chart. In addition, where corrections have been made in the data shown by the original chart a notation to this effect appears near the date of issue.

90. **Conventional Signs.**—a. The conventional signs, abbreviations and systems of lettering for use on charts are found in FM. 21-30 and column 4 and 5 of the sheet of standard symbols and in Correspondence School text "Military Abbreviations and Symbols." Of particular importance under this heading are the abbreviations relating to bottoms and the general abbreviations, since it is of interest to landing personnel to know what character of bottom they will encounter in landing men and materiel without wharf facilities.

b. With regard to notations as to depth, it is standard practice to use both depth curves and numbers to show depth in feet or fathoms, the depth shown being taken at mean low water. The showing of depths in fathoms is exceptional in coast or harbor charts, depths on these being shown in feet. In any case an explanation of the unit used usually appears in the legend.

c. Works of man or terrain features on shore are shown on charts in the same manner in which they are shown on topographical maps, except that, where the height or prominence of an object makes it a good landmark, it is customary to make a note of the fact, giving characteristics of the object, its height and, sometimes, width. In British Admiralty charts,

the practice exists of putting on the border of the chart a panorama which shows the general appearance of the coast line or harbor entrance from seaward.

In general, also, in delineating shore characteristics no colors are used, conventional signs being in black on a buff or cream-colored background.

d. In some cases, contours or hachures are used on the landward portions of charts. The normal contour interval is twenty feet.

e. No grid system is ordinarily put on hydrographic charts.

f. With regard to direction, all charts issued by United States authorities have, at as frequent intervals as possible, a compass card graduated from zero to three hundred and sixty degrees in the divisions of one degree. The zero of this card indicates true north. Inside this card is a second card, graduated according to the points of the compass, whose zero points to magnetic north; thus, the declination or as it is called in nautical parlance, the variation, is shown graphically. There is also given a notation showing the annual change of variation, usually in terms of increase or decrease.

g. Bottom conditions appear in the form of abbreviations, i.e., g for gravel, **hrd.** for hard, **sft.** for soft, etc. As all charts carry a definition of the abbreviations used in the particular chart, and as a complete list of these is also to be found on the "Sheet of Standard Symbols" their interpretation should be simple.

h. Aids to navigation are of comparatively minor importance to troops engaged in landing operations. However, it should be remembered that the universal rule for the placing of channel buoys is that red buoys are placed so that they will be on the right of the channel on entering it, or on moving upstream, and black buoys on the left. Also, for the benefit of students who may be unfamiliar with nautical phraseology, it is thought well to give here a definition of the most commonly used types of buoys. A **nun** buoy is made in the form of a cone, and is anchored with its apex uppermost, a **can** buoy looks exactly like its name, and is anchored with its long axis vertical; a **spar** buoy consists of a single spar, about twelve inches in diameter, anchored so that it floats in a vertical position with about ten feet showing above the water. Incidentally, as all anchored buoys must swing with the tide or current to some extent, these can be used to give an instant indication of the direction of the flow.

In connection with the identification of can buoys (see preceding page) there is a possibility of confusing them with a certain type of mooring buoy. The latter is usually a large cylinder with about twice the diameter of a standard can buoy, usually painted black, and with an eyelet bolt or short length

of chain thru which to moor, fastened to its uppermost surface. Also, it is invariably placed outside the channel, if in a roadstead.

91. **Additional Publications.**—There are certain other publications which may be of value in landing or base defense operations, altho the information contained in them is mainly included, where applicable, in charts or the legends thereof. Two of these are of particular value. The first is the Light List. It is published annually by the Department of Commerce, and contains information as to the name, character, color, and period of light of each light within the area along the Atlantic Seaboard and Gulf Coast. Similar lists are published by many foreign governments for the coast lines under their control or cognizance. Second, and more important, are the Tide Tables, published annually by the Department of Commerce in three editions. The first, known as the General Tide Tables, gives information about the tides in all of the more important ports in the world. The second is the Atlantic Coast Tide Tables, for eastern North America; and the third is the Pacific Coast Tide Tables for Western North America, Eastern Asia, the island groups included between these coasts and a few others to the southward. All of these give, for the locality in question, the time of every high and low water for every day in the year, and the height of each of these above mean low water. Altho the possession of these tables is desirable for officers engaged in landing operations, and altho familiarity with their use and interpretation is of value to all persons engaged in such operations, their possession by the individual is not essential, as they are issued to the cruising vessels in the Navy.

92. **Factor to be Considered in Making a Chart Study.**—a. Maps of land areas which border on water do not furnish sufficient information as to the places along the shore line at which landings can actually be made. On the other hand, hydrographic charts do not always give, in sufficient detail, information as to the nature and character of ground in the immediate vicinity of the shore line. Where practicable, the two types should be used in conjunction with each other. To supplement the information gained from charts a personal reconnaissance of the shore line from seaward should be made wherever possible, but where such reconnaissance is not possible, charts, or charts and maps of the areas involved should be studied with a view of obtaining information necessary to effect a safe and rapid landing.

b. In making a map, chart, or map-and-chart reconnaissance, the types of boats to be used should be considered in conjunction with the characteristics of the shore line. In considering the types of boats, attention must be paid to the following features:

(1) Draft, both loaded and empty.

(2) Speed.

(3) Backing power.

(4) Rigidity of construction and ability to withstand shock and abrasion (seaworthiness).

(5) Motive power.

(6) Manner in which propeller(s) and rudder are attached.

(7) Type of construction (e.g., whether with flat or keeled bottom, etc.).

c. Having in mind the type of boat available, a study of the shore line as depicted should be made. The items to be noted in making such a reconnaissance should include:

(1) Length, in yards, of stretches of beach suitable for landing.

(2) Distance from shore line (at mean low water) at which the types of boats available may be expected to ground.

(3) Character of water at shore line; whether surf or smooth.

(4) Character of bottom between grounding point and water's edge. This feature is particularly important, as it must be remembered that troops making the landing must traverse this area on foot, carrying their personal equipment and arms, and in some cases, moving light wheeled vehicles.

(5) Underwater obstacles, such as reefs, bars, isolated rocks, etc., which would endanger boats of the type available.

(6) Character of soil at landing beaches.

(7) Location and character of vegetation nearest to shore line.

(8) Prevailing winds at landing beaches.

(9) Suitability of beach and vicinity for landing seaplanes, if same are present.

(10) Times of maximum high water and of minimum low water.

d. With regard to adjacent terrain the following items should be noted:

(1) Points inland from which infantry-weapon fire can be placed on the selected beaches.

(2) Most advantageous routes from the beach, by which towns or other strategic points in the vicinity of the beach can be reached.

(3) Points along the route or routes mentioned above at which resistance is most likely to be encountered.

(4) Points offering good observation to the landing force in its advance from the shore line.

(5) Points nearest the beach at which measures may be taken to interfere with or divert to the use of landing force (a) hostile traffic, (b) local lines of water supply, (c) local public utilities, such as railways, electric-transmission lines, telegraph or telephone lines, gas lines, fuel supply, etc.

(6) Location of possible source of fresh water (other than the above) in the vicinity.

93. **Limitations.**—Hydrographic charts, being primarily designed as navigation aids, have certain limitations and disadvantages when employed as military maps.

a. **Mercator Projection.**—The Mercator projection is normally used on hydrographic charts. This projection assumes the meridians of longitude to be parallel and does not take into consideration their convergence at the poles. Hence, the distortion of a Mercator projected map or chart is zero at the equator and infinity at the poles. This greatly facilitates the marking off of latitude and longitude with dividers on these charts, but also greatly distorts earth masses and distances. In the absence of an overprinted military grid, the lines of latitude and longitude can be used in conjunction with an improvised coordinate square to give geographic coordinates.

b. **Distances.**—Distances are normally expressed in **nautical miles.** A nautical mile equals one minute of latitude which equals 6080.20 feet or 1.15 statute miles. The term **knot** as used by the Navy and by Marine aviation is the speed of one nautical mile per hour. Nautical miles and knots may be readily converted to statute miles by multiplying by 1.15. To convert statute miles to nautical miles, multiply by .87.

SECTION 12

FOREIGN MAPS

94. **General.**—a. The basic principles of map reading apply to all maps, foreign and domestic. If the soldier is capable of applying these fundamentals intelligently to maps of American design he will require no special or intensive instruction to enable him to read maps from other sources. Maps which will be used in many theaters will have been copied either by us or our allies from foreign maps. Intelligent use of these maps involves not only the mechanical and technical steps of map reading, but also the ability to evaluate the accuracy and limitations of the map information. Europe is the most completely mapped of all the continents. A fair proportion of North America also has been adequately surveyed, but the map coverage of the rest of the world leaves much to be desired both in extent and accuracy.

Maps employed in the early phases of many operations will undoubtedly leave much to be desired. As the operation progresses the inaccuracies must be corrected and the inadequacies supplemented by aerial photographs and personal reconnaissance. All ranks and services must be impressed with the importance of reporting map errors and omissions.

b. **Sources.**—(1) British.—The best world map coverage available to us is that offered by the Geographical Section of the British War Office and the Survey Directorates of the Commonwealth and Colonial governments. Since 1940, the British mapping policy has been the direct utilization of existing maps of foreign areas without change of sheet lines or characteristics. First editions will be direct copies, frequently in continuous tone or half-tone, with no change from the original other than legend translation and the addition of a grid. Later editions will contain such revisions and standardizations as are possible.

(2) French.—French maps have the reputation of being both accurate and clear. Their colonial possessions have been mapped extensively. At the start of the present conflict the best maps of the northern two-thirds of Africa were French.

(3) Dutch.—Netherlands maps are of high standard, detailed, and of good clarity. Their maps of the Netherlands East Indies are excellent. Belgian maps are similar to the Netherlands.

(4) Russian.—Although difficult to obtain until recently, Russian maps have excellent draftsmanship and are apparently very accurate. Symbols are often complex and town symbols are keyed to population. In the Siberian areas roads and trails are shown in terms of summer or winter use.

(5) Scandinavian.—Danish, Norwegian, Swedish and Finnish maps resemble each other closely. The maps are excellent, but make little use of color.

(6) German.—As might be expected, German maps are extremely detailed and accurate, but an overabundance of detail sometimes destroys the clarity of their maps.

(7) Italian.—The Italians have done little with mapping with the exception of North Africa where they have produced good maps of their own colonies including the hitherto little-known Ethiopia.

(8) Japanese.—Japanese map standards vary from poor to excellent. They are very often inconsistent, particularly in the Anglicized spelling of place names.

c. **Marginal information.**—An analysis of the marginal data is even more important when dealing with foreign maps than when working with domestic maps.

(1) Authority.—The reliability of a map is largely dependent on the organization that issued it and the purpose for which it was made. Governmental agencies are more reliable than commercial firms; general purpose maps are more reliable than special purpose maps, such as road or railroad maps.

(2) Dates.—Maps are only reliable as of the dates of original survey and subsequent revision. Remember that revision does not necessarily mean a complete modernization of a map.

(3) Conventional signs and symbols.—Foreign signs or symbols whose meanings are not obvious will be shown on the margins of the map.

(4) Scale.—In general, the larger the scale, the more accurate the map. There are exceptions to this rule however. "Blow-ups" or enlargements, for instance, can be no more accurate than the smaller scale map from which they have been enlarged. "Blow-ups" can generally be identified by the relative coarseness of composition.

d. **Scales and distance.**—It is common among all nations and on all maps to show the scale of the map as a representative fraction or RF. The unit of measure employed by the nation does not affect this relationship, whether it be the cho of the Japanese, the metre of the French, or the mile of the English. If the unit of measure employed on the map is inconvenient or unfamiliar to the user, a graphic scale reading to the desired unit may be readily constructed once the RF is known.

Most maps which do not show miles will at least show the metric system. Distance expressed in kilometers can be converted into miles by multiplying by 5/8 or, if a more exact conversion is desired, by 0.62. For a rough approximation of

the number of yards, multiply the number of meters by 1.1, or for a more exact determination, by 1.094.

In the event that the contour interval is stated in terms of meters, this may be converted to feet by multiplying by 3.3, or more exactly by 3.282. In preparing profile and visibility diagrams, however, it is not necessary to convert to the usual English or American units, as the profile produced will have the same outline regardless of the selected unit.

95. British Grid System.—Most of the foreign maps which come through British channels have, as an integral part or as an overprint, the British Military Grid System. This grid system has the property of being adaptable for accurate surveying without making various grid north corrections such as are necessary with the United States Military Grid. This property is obtained by keeping the areas rather small and also relatively long and slender with the longer axis of the area being in the direction either of a parallel or meridian. The general shape of a country, continent, or other area to be gridded usually lends itself to a subdivision in one direction or the other. For example, Netherlands East Indies is easily divided into long, slender areas running east and west, while East China is more readily divided into areas running north or south.

Each area is named as a zone or belt, for example, Netherlands East Indies Zone of Australia Belt # 5. All British Grids are printed in a fixed color throughout any certain zone, the colors for the series of zones being so arranged that no two adjacent zones will be the same color. There is no overlap between grid zones.

A grid zone is ordinarily divided into squares of 500 KM on a side. Each basic square is assigned a letter, the letters being alphabetical, reading from left to right and down within a zone, omitting the letter "I." Each 500 KM square is further divided into 100 KM squares, each of which is designated by a letter arranged in the same order as the 500 KM square letters. Thus, a 100 KM square of a zone may be identified by two letters, the first of which represents the 500 KM square, and the second the 100 KM square. Some zones are so long it becomes necessary to repeat the series of 500 KM squares. In this case, more than one 100 KM square will be assigned the same letter. Other zones are so small that neither the 500 KM or 100 KM squares appear; hence, no letters will be used in the grid reference.

On maps of scale 1:250,000 to 1:500,000, the letters identifying the 500 KM square and the 100 KM square are both shown on the face of the map. Ordinarily, on maps of scales 1:250,000 and larger, only the 100 KM square letters are shown, although the letter identification of the 500 KM square may appear in the grid index diagram on the margin of the map.

The spacing of the grid lines is controlled by the scale of the map. On maps of scales 1:20,000 to 1:100,000, the grids are spaced at 1,000 meters and on maps of smaller scales they are spaced at 10,000 meters. In a few cases, grids on the 1:100,000 scale map will be spaced at 10,000 meters.

To write coordinates:

a. Write the 500 KM square letter.

b. Write the 100 KM square letter. If all pertinent letters are not shown, it may be necessary to sketch out the basic square arrangement (fig. 70) to be sure that the proper letters are applied.

c. Write the east-west coordinates from the lower left corner of the appropriate grid square, estimating or measuring to the smallest reading desired.

d. Write the north-south coordinates in the same manner, without a hyphen or dash between the two coordinates. (READ RIGHT UP applies on the British grid just as on that of the U.S.)

e. Always omit the small numbers which precede the large grid numbers in the margin.

Figure 70 shows how a map might have British grid lines placed on it. The letters are always arranged in the same order, no matter whether the squares are 100 KM or 500 KM. Every letter in the alphabet is used except the letter "I." The 100 KM square "R" of the 500 KM square "G" is designated as (G)R. It may be further divided into tenths and hundredths. A point that is 39 KM right of the southwest corner of this square and 63 KM above the southwest corner is designated as (G)R3963. If two digits are used in reading right, two must be used in reading up; if three are used in reading right, three must be used in reading up. For example, right 31, up 285 must be written 031285 in order to be understood which figures mean right and which mean up. One must know the arrangement of the letters to find the 100 KM square.

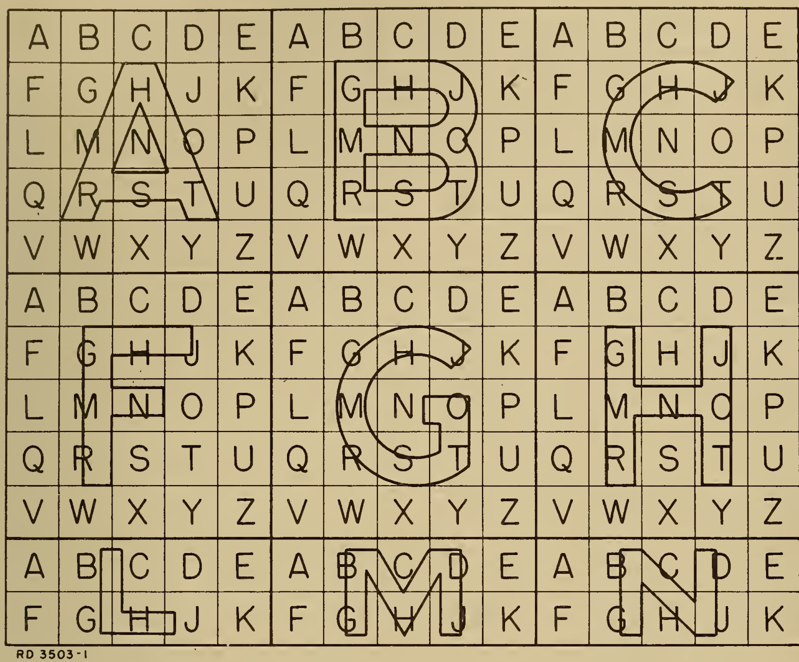


Figure 70.

96. French Geographic Grid.—French maps show a different geographic grid than the English and American. The French system bases its grid on a prime meridian established as passing through the observatory at Paris. Instead of using degrees as a unit of angular measure, the French divide their circle into 400 grades* (written 35G, 259G, 365G, etc.). Each grade is subdivided into 100 minutes and each minute further divided into 100 seconds. One grade equals .9 degree, so conversions from one system to the other may be easily calculated.

* Grade, pronounced grad.

Following are original Japanese Symbols that would appear on an original Japanese map.

NOTE: Many of their symbols bear characteristics similar to our standard symbols, some indicating similar objects while others indicate entirely different objects.

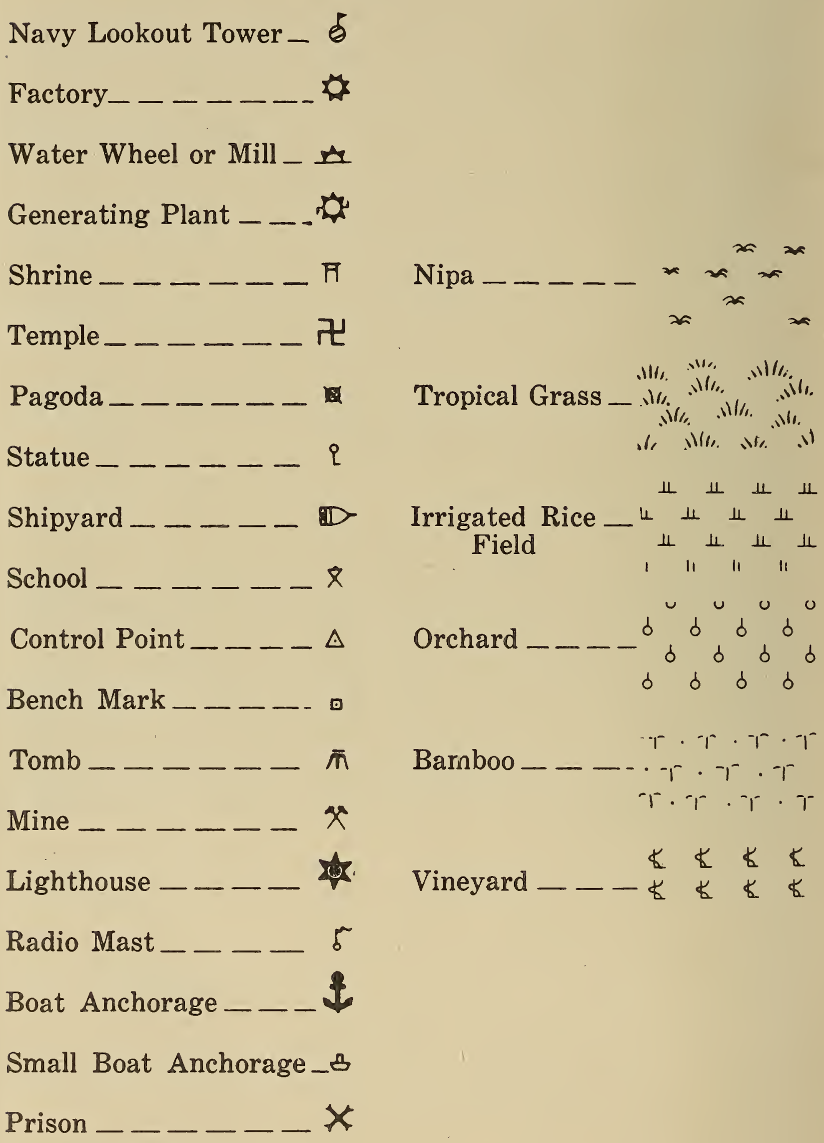


Figure 71.—Japanese Map Symbols.

The Following Publications may be Obtained from the Correspondence School upon Request by any Officer of the Marine Corps

Title	Volume	
Administration, Marine Corps	II	
Artillery	XXXIII	
Combat in Woods	XXXIX	D
Command and Administration	XLV	A
Defensive Combat of Small Infantry Units	X	
Description of Marine Corps Artillery, Weapons and Ammunition	XXXIII	Part 3
Elementary Combat Intelligence	XLI	
Employment of Artillery by the Infantry Commander	XXXIII	Part 5
Estimate of Situation and Operation Plans and orders	XXXII	A
Field Artillery Reference Data	XXXIII	Part 4
Field Fortifications	XI	
First Aid and Field Sanitation	XXII	
General Organization of Marine Corps Artillery	XXXIII	Part 2
Infantry Antiaircraft Defense	XVIII	
Jungle Warfare	XVII	
LFM, Chapter XI, Interior Guard Duty and Guard Mounting	XIII	
Light Tank Tactics	XXXIV	
Map and Aerial Photograph Reading	III	A
Message Writing	IX	B
Military Discipline, Courtesies and Customs of the Service	XV	
Military Government	XLVIII	
Military Principles	XXX	
Military Sketching	III	C
Military Symbols and Abbreviations	III	B
NAV-5-K	XLV	B
Night Attack	XXXIX	C
Notes on U.S. Marine Corps Aviation	XX	
Offensive Combat of Small Infantry Units	VIII	
Organization of Marine Infantry Regiment	VII	
Pursuit	XXXIX	E
Raids	XXXIX	F
Reconnaissance in Force	LXIV	A
Reference Data	XXXI	B
Retrograde Movements	XXXIX	A
River Crossings	LXIV	B
Sample Operations Orders	XXXII	B
Scouting and Patrolling	VI	
Signal Communications in the Infantry Regiment	IX	A

Title	Volume	
Special Operations of Infantry Units	XXXIX	B
Staff Principles and Functions	XL	
Tactical Principles	LXIV	C
Tactics—Decisions	LXIV	D
Technique of Rifle Fire	IV	B
Terrain Appreciation	XXXII	C
The Solution of Map Problems	XXXI	A
U.S. Marine Corps as Component Part of the U.S. Navy	I	
Weapons	IV	A

NOTE: The volume number corresponds to the number of the first subcourse to which the text applies. Where a subcourse uses more than one text, each text is designated by a letter in addition to the subcourse number.

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